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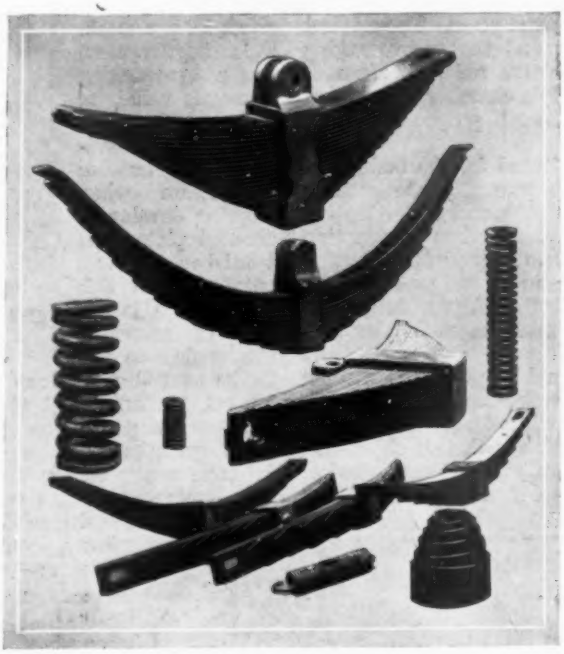
Spring Production for Railway Rolling Stock

A Great Western Railway Development

New Installations have improved the quality, reduced repairs, and effected considerable economy. Results on a productive basis have exceeded expectations.



Some examples of the wide range of Springs produced.

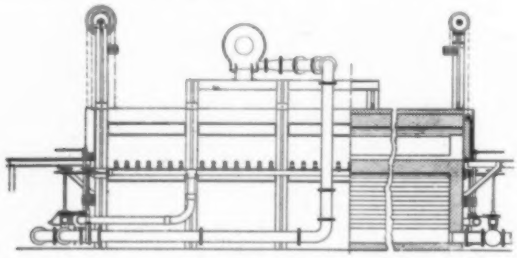
ABSENCE of vibration is one of the outstanding features of modern transport, and in no type is this emphasised more than in rail transport. Whether running at slow or express speeds the degree of steadiness in modern rolling stock is remarkable, a feature which considerably enhances the comfort of travelling, ensures the transport of goods with the minimum of disturbance, increases the life of the rolling stock, and ensures greater safety. While many factors are involved in obtaining a high degree of comfort and maximum service in this respect, the influence of well-designed and properly constructed springs cannot be overestimated. Consider a locomotive, for example, however well the rails may be laid and kept, there are always running shocks in addition to the weight carried. These shocks first affect the wheels, from which they are transmitted through the axle-boxes to the frames, the engine, and the boiler. The faster the locomotive runs, the more powerful do these shocks become, and consequently are more destructive to the rails and to the engine. In practice the faster a locomotive is designed to travel the greater the need of perfection, not only in the arrangement of the springs, but in the quality of material used and in the technique of their manufacture.

The springs for a locomotive have been taken as an example, but it will be appreciated that many different designs are necessary to meet the requirements of the wide range of transport equipment included in the general term, rolling stock. All forms, however, are embraced by two main types—viz., laminated or plate springs and coil springs. The laminated springs, for instance, depend upon the static load, the disposition of the centre of gravity, the ratio of spring centres to the track, co-efficient of friction between wheels and rails, braking effects, etc., but the great principle underlying the spring is the elasticity of the steel of which it is built. When a spring plate is deflected under ordinary working conditions a stress is imposed on its surfaces and through its sections, implying that a corresponding force in the plate has been required to resist fracture. This internal force may be required to resist tension, compression, shearing, or torsion, but whatever the nature of the external force, the resistance of the plate should be its equivalent, otherwise its elastic strength will be exceeded. Generally speaking, in laminated springs only tension and compression need be considered, and these are invariably applied primarily by running shocks which are cumulative to the static loading. Whatever form the spring may take its effectiveness is dependent upon its elasticity, this being the amount a spring will deflect under a given load without having its form permanently changed. The amount a spring will bend under a given load is dependent on the number of plates, their thickness, length, and breadth, and on the material of which they are made.

In drawing laminated springs it is considered to be an advantage to make straight lines from the strap or buckle to the ends of the longest plate and arrange each succeeding plate to conform with the straight line principle. This method equalises the elasticity of the spring, but a sufficient number of plates are necessary to give adequate strength near the attachment of the hanger. Sometimes one long plate is made thicker than the remainder, but modern practice favours the use of plates of similar thickness throughout. It must be remembered that the greatest permissible deflection, up to the breaking of the spring, decreases with the cube of the thickness of the plate, and its strength increases with the square of the thickness. Thus, for a given deflection a thick plate must bear a greater comparative load, and this is reflected in the

number of breakages of thick plates in comparison with thin plates of the same spring.

It has already been pointed out that springs have been improved, not only as a result of superior design but also by the use of high and uniform quality steel, improved treatment of the steel as a result of a fuller knowledge and better production equipment. This is well illustrated in a recent development at the Swindon Works of the Great Western Railway Company. The whole question of spring production had been the subject of the closest possible investigation by the engineering staff of these works, and initial spring making, which was in the nature of experimental work, was in progress for some years. The original experiments proved satisfactory, and the spring-making plant was extended to a productive unit, the furnace equipment consisting of three triple chamber furnaces of the original type and one general purpose furnace, 8 ft. 6 in. × 7 ft. 6 in.



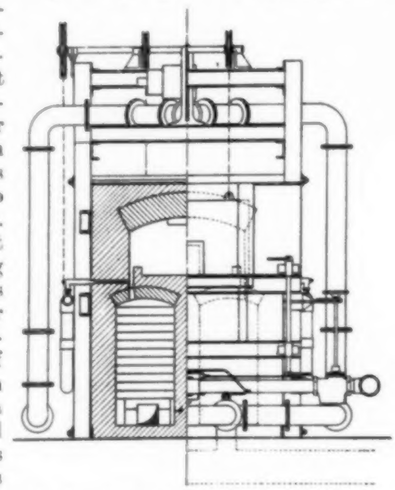
25 ft. × 2 ft. 9 in. Bar Heating Furnace for making Coil Springs.

Further experiments were instituted for the making of coil springs. These experiments proved to be entirely satisfactory, and as a result a double-ended bar-heating furnace, 25 ft. × 2 ft. 9 in., was installed in conjunction with a special 5 ft. × 4 ft. furnace, designed for operating over a wide range of temperatures and suitable for tempering the coils, a process which had previously been carried out almost exclusively in furnaces of the lead bath type.

When the first part of the coil-making plant was working satisfactorily on a commercial basis, the Company proceeded to concentrate the whole of its laminated and coil spring making in one department. With this object the department was enlarged to an approximate size of 185 ft. × 140 ft., a complete installation planned, and further furnaces added. The installation included nibbling and slotting machines, coiling machines, spring-testing machines, etc., while additional furnace equipment included four improved triple chamber furnaces and an 8 ft. 6 in. × 7 ft. 6 in. general-purpose furnace for laminated springs, and a second 25 ft. × 2 ft. 9 in. double-ended bar-heating furnace for the coil-spring department. In keeping with modern practice thermo-electric pyrometers are installed in each furnace, and are connected to multipoint permanent indicators, a number of which are located conveniently in the departments, while two- and four-point recorders are located in the staff office suitably fitted up for making temperature records of any of the furnaces.

Illustrating one of the Bar-heating Furnaces for Coil Spring making. Note the Coiling Machine at the end of the Furnace.

It is obvious that in times of depression more than ordinary care must be exercised to ensure that expenditure on new plant is justified. That the original experiments proved satisfactory is indicated by the adherence to similar plant to complete the equipment for establishing the department as a productive unit. All concerned in this installation are deserving of congratulations as the results obtained on a productive basis have exceeded expectations. Not only has the cost of production been considerably reduced but the quality of springs is vastly improved. Under the old system plates in laminated springs developed cracks at the rate of approximately 100 per week, with modern equipment this has been reduced to about 12 per week. This improvement has a far-reaching economic value, as a locomotive, for instance, is immediately put out of commission when a spring develops a cracked plate, and besides the loss entailed from this cause there is the cost of returning the engine to the works as well as the cost of repairs. Gradually repairs are being reduced and the department is concentrating more on the production of new springs.



End section and elevation of 25 ft. × 2 ft. 9 in. Bar-heating Furnace.

The qualities of steel used in the manufacture of springs in these works consist mainly of straight carbon steels. The laminated springs consisting of a British standard open-hearth steel designed for water hardening, a practice favoured for railway work in Europe. This steel has the following composition :—

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
0·5/0·55	0·2/0·25	0·65/0·75	0·04	0·04

The tensile strength of this steel as rolled is required to be 43 tons per sq. in., while after tempering it should have a tensile strength of 65 tons per sq. in. and an elastic limit of 55 tons per sq. in.

A straight carbon steel is also used for coil springs, but of a higher carbon percentage than for laminated springs. This is suitable for oil-hardening. This is also an open-hearth steel and has the following composition :—

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
0·9/1·1	0·2/0·25	0·6/0·7	0·04	0·04

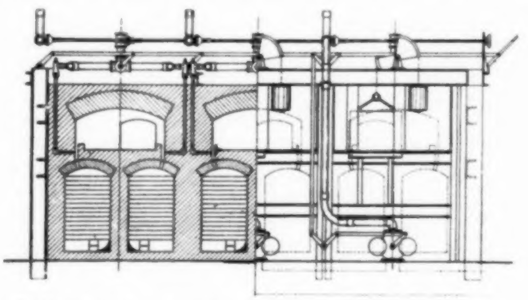
As rolled this steel has a tensile strength of 60 tons per sq. in., and after heat-treatment 82 tons per sq. in. tensile with an elastic limit of 60 tons per sq. in. These steels are obtained in required sizes from British steelworks, usually from Sheffield.

In the production of laminated springs, of which this Company construct about 250 varieties, carrying from 4 to 22 plates, to accommodate its wide range of rolling stock, it is customary first to cut off plate lengths. Each plate is then drilled at the centre and the hole rounded to facilitate movement. Spearing the ends as well as punching studs and slots is usually done in one operation, dies being prepared carrying a register pin for locating the plate.

Greenwood and Batley machines are arranged to perform these operations. It is customary in some works to carry out these operations on the cold metal, but at these works the ends of the plates are heated. Hot forging makes no appreciable difference in the quality of product, as any structural deformation resulting from cold forging is heat-treated back to normal when the plate is heated for curving and hardening. By hot-forging, however, it is possible to perform a number of operations simultaneously with considerably less power and a lower maintenance cost on machines.

With such a wide range of springs the Company consider it more economical to adopt hand fitting for these springs. In this process the various plates, including the backplate, are delivered to the fitter ready for fitting—*i.e.*, they are speared, holed, studded, slotted, etc. His job is to curve the plates, harden them out, temper them, and set them as required to produce a reasonably well-finished spring. Knowing the required curve, the fitter's initial operation is to mark out on his fitting plate a curve joining the true camber points, from which a pattern is made against which the backplate can be fitted. In this way it will be noted that the backplate will be given the desired camber, with no allowance for the ultimate nip and pull which will be included in the finished spring. This preliminary curving of the backplate is necessary to ensure that the overall or centre to centre length is correct with the desired camber, with suitable allowance for the sweep of the plate.

When the backplate has been made to conform with the pattern and is found to be accurate, the fitter proceeds to



Sectional and external elevation of a Triple-chamber Furnace.

"set" it less than the specified camber, the amount varying with the particular design of spring. With a standardised design this initial work need not be repeated, the pattern will be available to proceed with the backplate at once. The backplate having been set it is hardened and tempered, when the fitting of the remaining plates can proceed.

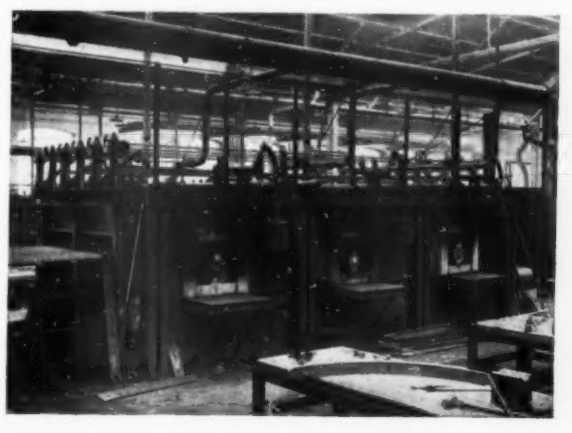
The work is carried on in sets of two or four springs, the fitter setting two or four backplates so that two or four springs will be proceeded with simultaneously. The plates are heated to a temperature of just under 1,000° C., and when taken from the furnace each plate is readily "pinched in" to the one which will be superimposed in the complete spring, and, when fully curved, it is quenched out in water, in which condition it is ready for tempering. This is effected by heating the plates to a temperature of 400° C.

Some manufacturers prefer to keep the temperature of the plates at about 900° C. because there is rapid rise in surface decarburisation above this temperature; on the other hand when the lower temperature is used there is a risk of quenching at too low a heat, which reduces the spring quality of the steel. The prevention of excess oxidation during the heating process is simply a question of proper furnace design and operation. With such a design, and the furnace operated so that soft hazy heats are produced, giving a reducing atmosphere, the temperature can be about 1,000° C. with advantage. In these works it has been demonstrated that results obtained from practice along these lines have been most gratifying, and illustrate the economy which follows proper furnace design and operation.

As the springs pass from the fitter's hands to the final finishing stages, it is the usual practice to test them. The basis of these tests formerly was to obtain a deflection at which no measureable set could be observed when the spring was released. The springs, however, are invariably

A pair of Triple-chamber Furnaces. Note arrangements to accommodate the Spring Fitters.

made on the high side in regard to camber, because it is easier to effect a reduction than to increase it. The steam scrag is used for these experimental tests. This machine is so designed that a horizontal table, upon which the spring is placed, has attached to it a strong steam cylinder, capable of exerting considerable pressure on the spring. Very rapid strokes can be given and the machine is very effective. Actually, in hand-fitted springs this scrag testing is an important factor governing the life of the spring. If under-tested, inherent defects are likely to pass undetected, while overtesting may cause a crippling effect equivalent to several years' service. Moreover, a good scrag assists in the effective bedding of the plates and frequently performs the final fitting. Subsequent to the scrag tests the springs are dissembled, and each plate carefully examined for defects. The practice at the Great Western Works is to oil each plate; this facilitates inspection and has protective advantages to the plate. As

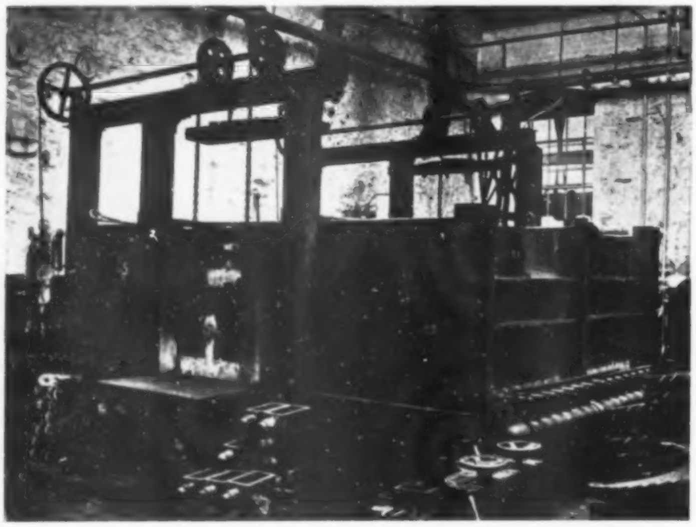


A closer view of a Triple-chamber Six-door Furnace, of which there are seven installed.

each plate is found to be sound the spring is reassembled and finished preparatory to a final test on a specially designed testing machine. In these works an improved type of machine is installed, which is designed for testing laminated, coil, and elliptical springs. It is operated by hydraulic power and has a capacity of 20 tons.

The machine is an Avery production and is designed for a double purpose : to make both static and dynamic tests on springs. When it is desired to make the weighing test, the pump is regulated by handwheel to give a slow movement to the ram, and the load on the spring is registered through weighing levers to the steelyard. For the dynamic or repetition test the pump is controlled by the hand-lever to give quick movement of the ram. The machine consists generally of a weighing machine with an improved steelyard for indicating the strain, and a hydraulic press for applying the strain. The pressure required for working the ram of the hydraulic press is 1 ton per sq. in. The spring to be tested is placed in position upon the platform, and the ram of the hydraulic press is then forced downwards to apply the strain. The strain is transmitted through the weighing lever to the steelyard, and there balanced and indicated by a travelling poise. The weighing portion of the machine is entirely self-contained, which effectually secures the main levers and suspension links from dust and grit. Machine cut gearwheels ensure a steady movement of the poise, gradual increments of load are obtained, and the pressure of the hand upon the steelyard is entirely avoided.

The graduations are engraved to read from zero to the maximum capacity of 20 tons, by smaller divisions of 1 cwt., and a vernier scale upon the poise subdivides these 1-cwt. divisions by 14 lb. The steelyard is also provided with a tare bar and poise for balancing the weight of the springs. The bar is graduated from zero up to 10 cwt. by subdivisions of 14 lb. A graduated deflection scale is fitted upon the cylinder, and this is traversed by a cursor, which is controlled by a rod attached to the top platen. Deflections of $\frac{1}{10}$ in. are indicated by this arrangement. The hydraulic press is designed to give a downward pressure upon the springs up to 20 tons, and the ram, when up, gives a clearance of 30 in. between its lower face and the top of the platen. The coil springs, to which reference has been made previously, are machine made. Machines being fixed at either or both ends of the bar-heating furnace, the end of each bar being attached to a machine immediately it is drawn from the furnace, and the machine operated to produce a regularly pitched coil. Allowance is made for "set" due to subsequent scragging, the amount varying, of course, with the particular design of the spring. The manufacture of volute springs are on somewhat similar lines to that for spiral springs. In these works it was interesting to note that the steel heated for each type of spring manufacture showed no signs of scaling in the furnaces, oxidation taking place only after each plate or bar was taken out to perform shaping operations.

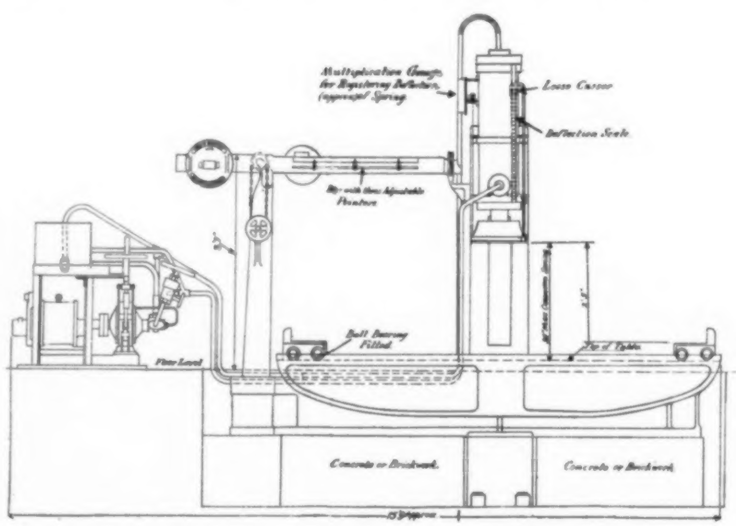


Illustrating a special 5 ft. × 4 ft. Furnace for Tempering the Coil Springs.

According to the engineering staff at these works, the success that has attended their efforts to convert the spring department into a productive unit is largely due to the effective design of the furnaces, but while there can be no question that modern design in furnace construction has done much to remove difficulties, the manner in which the furnaces are operated, as well as the technique of manufacture, have had an important contributory influence on the remarkable success of this development.

In view of the fact that the furnaces have contributed in no small degree to this achievement a description of this installation will be of interest. All are gas fired and of the "Revergen" type, constructed by Davis Furnace Co. For the making of laminated springs, seven triple-chamber furnaces have been installed. Three of these batteries are each provided with two chambers 7 ft. long × 3 ft. wide × 1 ft. 4 in. high, and one chamber 7 ft. 6 in. long × 3 ft. wide × 1 ft. 4 in. high, and four batteries are each provided with three chambers 7 ft. long and 3 ft. wide × 1 ft. 3 in. high—21 working chambers in all. A rise-and-fall counterbalanced door is provided at each end of each chamber, there being, therefore, six doors to each triple-chamber battery. A small supplementary door is provided to each of the hardening chambers for tag and heating when required. In these furnaces the setting of the springs is carried out at 1,000° C., whilst the subsequent heat-treatment includes hardening at 820° C. and tempering at 400° C.

Each chamber in each of the batteries is provided with its own pair of regenerators, which are built into the structure beneath the floor of the heating chamber. These regenerators ensure the maximum amount of residual heat in the products of combustion passing through to the flue outlets being recuperated, and returned to the working hearth in the form of highly preheated air. Each chamber



Front elevation of the Avery Spring Testing Machine installed.

with its regenerators, is under separate control, and can therefore be worked as an entirely independent furnace if required.

The regenerators are built of massive chequer brickwork, and are divided by a partition wall, thus making two distinct sections—one on the left-hand side and one on the right-hand side—each section being connected to its respective side of heating chamber by ports, which become alternately combustion or exhaust ports according to which side of the chamber is being fired. Each section of regenerator chamber is connected to its own system of gas and air inlets and exhausts, but each system of gas and air inlets and exhausts is connected by a main control cock, or cocks, and operated by a common control lever and change-over gear.

Two coil-spring furnaces are installed, each having a heating chamber 25 ft. back to front × 2 ft. 9 in. wide × 1 ft. 9 in. high. These furnaces are used for heating the bars required for the manufacture of coil springs, the temperature of operation being approximately 1,000° C. A counterbalanced rise-and-fall door is provided at each end of the furnaces. Each half of these furnaces is under separate and independent control, having its own pair of regenerators built in beneath the floor. Any one half of the furnaces can, therefore, be worked as a separate furnace if required.

The equipment also includes two spring buckle and general-purpose furnaces, each having a heating chamber 5 ft. 6 in. × 7 ft. 6 in. × 1 ft. 6 in. high. They are used for the making of spring buckles and general parts required to be made in this department, the temperature of operation being 1,000° C., or higher if necessary. They are provided with two rise-and-fall doors at each end, so that four fitters can be kept going at one time. Double regenerators are built into the structure beneath the floor of the heating chamber, as in the case of the furnaces previously mentioned.

A special furnace is installed for hardening, tempering, and setting of the coil springs. It has a heating chamber 5 ft. × 4 ft. × 1 ft. 6 in. high, and provides for a wider range of temperatures than is usual. All the furnaces are built throughout of the highest class of Scottish refractories and "Sil-o-Cel" insulating materials. They are massive and durable, and are built in pits to bring the working level to a suitable height.

As previously stated, each furnace compartment is fitted with a pyrometer and connected to one of a number of multi-point thermo-electric pyrometer indicators conveniently placed for checking the working temperature, and these operate in conjunction with recorders which give simultaneous temperature records on one chart.

One of the 6-point Thermo-electric Pyrometer Indicators.

A 2-point Recorder connected for giving a Temperature Chart for any one of a number of Furnaces.

CHROMIUM PLATING REGULATIONS.

In view of the fact that a number of objections have been raised in regard to the draft regulations on chromium plating, issued on April 29 last, H.M. Chief Inspector of Factories has recommended that the regulations be revised. This revised draft has been published to comply with the provisions in the Factory and Workshop Act, 1901, but it is understood that practically all the objections which have been raised will be substantially met in the revised draft.

The chief differences between the original and revised drafts are as follows :—

(*a*) In the original draft, Regulation 3 required that workers employed at a bath should be provided with rubber boots, and with aprons and bibs of rubber or leather. The revised draft permits greater latitude as regards the materials to be used. (Several occupiers objected to the requirement of rubber gloves under this regulation on the ground that they would be unsuitable in the case of persons employed in wiring and unwiring, but this requirement has always been limited to persons working at a bath, and it was never proposed that the use of gloves should be required in other cases.)

(*b*) Regulation 5 (*a*), which was couched in general terms in the original draft, has now been made more specific. The revised draft follows the terms of the corresponding regulation, which has been in force for some years in chemical works.

(*c*) A new Regulation (No. 6) requires the provision of drinking water. This requirement already applies to all factories and workshops employing 25 or more persons, and also to various classes of works irrespective of the number employed.

(*d*) A new Regulation (No. 9) has been inserted, prohibiting the employment at baths of young persons under the age of 18. It is understood that nearly all the persons employed at the baths are already over this age.

Two other objections have been raised which it is proposed to meet, not by an amendment of the draft, but by subsequent administrative action :—

(i) It was suggested that there was not sufficient ground for applying Regulation 1 to anodic oxidation as well as to the plating process on the ground that in the former case the solution is so weak and the current density so low that the provision of exhaust ventilation is unnecessary. Further investigation has been made on this point and has shown the presence in some instances of chromic acid in the air immediately over baths used for anodic oxidation, and the Secretary of State is therefore not prepared to exclude this process from the scope of the regulation. On the other hand, it appears that in certain conditions the amount of acid in the air may be so small as to be harmless, and it is proposed that the Chief Inspector should deal with such cases by exemption under the paragraph headed "Exceptions."

(ii) The fortnightly medical examination (see Regulation 8 in the revised draft) has been criticised as being over-frequent. In view of the rapidity with which the chromic acid affects the skin and mucous membrane of the nose, the Secretary of State would not be willing to agree to any general relaxation of this requirement, but the Chief Inspector will be authorised to extend the period between the examinations in particular cases if it is found after trial that this can be done without prejudice to the health of the workers concerned.

Red-lead Paint for Iron and Steel Protection.

Same Notable Recent Research Work.

(*Contributed.*)

MORE attention than ever is now being devoted in many different fields to the general subject of corrosion, which seems to become more baffling the more it is investigated. In this connection red-lead paint is, of course, well known to be a highly efficient method of protecting iron and steel against rust and corrosion, and considerable interest attaches to recent research work on the chemical reactions involved. Thus, according to E. Kindscher, for example, litharge or lead monoxide (PbO) and red lead (Pb_3O_4) interact slowly with linseed oil on storage to form a considerable proportion of organic lead salts of unknown composition, whereas such inter-reactions do not take place with white lead (basic carbonate) to any appreciable extent.

It is well known that the basis of linseed oil, as well as other "drying" oils, is linoleic acid in the form of a glyceride, which absorbs oxygen and becomes semi-solid. Undoubtedly, however, many other organic acids are present in small amounts in crude linoleic acids, and it is possible that the formation of lead salts in this way, with more than one organic acid, is one of the reasons for the valuable properties of red-lead paint.

In general, there is no real substitute for the latter, which, judging by the strong adherence of the paint, seems to combine chemically in some way with the iron or steel. Also the film or thin layer, consisting essentially of oxidised linseed oil and finely divided red lead, is extremely resistant to oxygen, carbon dioxide, and moisture, while at the same time sufficiently elastic to resist the expansion and contraction of the metal.

Essentially, red lead is made by the oxidation at about 645° F. of molten lead, with lead monoxide (PbO) as an intermediate stage, the latter being then converted to red lead (Pb_3O_4) by oxidising in air at a higher temperature, not over 1000° F., until the necessary degree of red colour is reached, an operation known as "colouring"; the manufacture of the lead monoxide being termed "drossing."

Apparently red lead (Pb_3O_4) is a definite chemical compound, although opinions differ on the subject, and according to some authorities it is a "solid solution" of lead peroxide (PbO_2) in lead monoxide (PbO). Also commercial red lead is Pb_3O_4, containing varying amounts of free PbO, depending upon the degree of oxidation and the exact method of manufacture.

During recent years a great advance has been represented by the production of stable liquid red-lead paints made of "non-setting" red lead, very low in free lead monoxide PbO, and supplied in various colours—that is, not only red, but also brown, black, olive, and green, for example, by the addition of other pigments such as lampblack, Prussian blue, and chrome yellow. The method of mixing dry red lead by hand in small quantities, as required, with the linseed oil and thinning with turpentine is now more or less obsolete, as the improved product supplied keeps in good condition, and it can only be emphasised that cheap and shoddy paint, especially for iron and steel work of all kinds, is the worst possible investment.

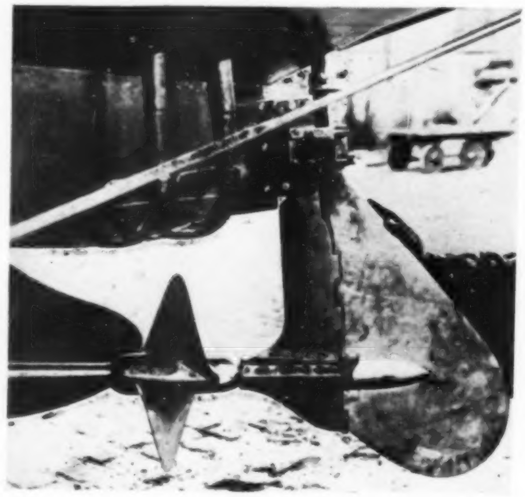
"Solidend" Tools.

Samuel Osborn & Co., Limited, supply "Solidend" tools in the finished state, that is, forged, hardened and ground, ready for use, but as many users prefer to do their own forging and heat-treating, they are now supplying S.O.B.V. "Solidend" blanks. These consist of a 50-ton tensile steel shank, having a full section of S.O.B.V. welded on, the size varying with the size and shape of the tool. Usually, with a 1-in. square tool a 1-in. cube of S.O.B.V. is supplied. It is claimed that these blanks can be forged and heat-treated without affecting the weld, and they are as easy to grind as a solid tool.

New Water Speed Record.

IN our last issue we were able to refer to the breaking of the world's land speed record by a British car driven by Sir Malcolm Campbell. Once again a striking testimony is paid to the efficiency and reliability of British products, by the fact that Mr. Kaye Don, driving "Miss England II.," has set up a new water speed record of 103·49 m.p.h.

"Miss England II." was built in 1930, and is fitted with two Rolls-Royce 12-cylinder supercharged racing aeroplane engines, of the same type as that used in the winning Schneider Trophy "S.6" seaplane in 1929. The main feature of these engines is that much of the material used in their construction is such that it has been possible to obtain a better power-weight ratio than has ever been



Propeller, Rudder, and Rudder Assembly of Miss England II.

achieved before. Each develops 2,000 b.h.p., and a feature of the boat's design is its unusual transmission. Separate shafts carry the drive forward from each engine to a gearbox in the bows. Thence a single shaft carries the drive downwards and sternwards to the propeller. To reduce water resistance one propeller only is used. This propeller is only 13 in. in diameter as it rotates at a speed of 12,000 r.p.m. It is clear that terrific strain must be set up in certain parts of the transmission and to combat this stress, very high quality steels were used. The crankshafts, clutch, steering, and many other parts were machined from drop forgings of "Super VNCA" steel made by the English Steel Corporation; this steel combines great resistance to shock with a tensile strength of over 60 tons per sq. in. For the rudders (bow and stern) E.G.C. nickel-chrome-molybdenum steel, known as "super S.H.N.C.," was used, the whole assembly being machined to close limits and treated to give a tensile strength of 100 tons per sq. in. The 13-in. diameter propeller, which has to bear almost more stress than any other part of the whole boat, was made from a forging of the "Super VNCA" nickel-chrome-molybdenum steel, as used for the crankshaft, etc. Finally, the propeller shaft, which is rather a remarkable piece of workmanship. Made of "Super S.H.N.C.," treated to give a tensile strength of over 100 tons per sq. in., it transmits over 4,000 h.p., although 20 ft. long and only 1⅝ in. in diameter. To produce such a long, thin shaft, free from distortion, is a task needing considerable care and experience. The setting up of this new record is a fine achievement, and great credit is due, not only to the pilot and all who were concerned in the design and construction of the boat, but also to those responsible for the manufacture of the materials employed. This achievement is largely due to the capacity of high quality British material for withstanding enormous stresses under exceptional conditions.

METALLURGIA

The British Journal of Metals.

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CONTENTS

METALLURGIA

THE BRITISH JOURNAL OF METALS.

CONFIDENCE WILL RESTORE NORMAL INDUSTRIAL CONDITIONS.

THE subtle effects of political developments throughout the world are clarifying the international atmosphere and creating a measure of confidence which has been strangely lacking during recent years. The world is gradually adapting itself to the new post-war conditions; a world completely disorganised is becoming a world reorganised, and the aspirations of subject peoples are essentially a proof that, instead of modern civilisation being decadent, it is truly progressive. Lancashire may feel sad about the loss—temporary, for certain—of Indian trade, but the ratification of the Delhi Pact by Congress is a vindication of Lord Irwin's broad-minded policy. Mr. Gandhi will now have the opportunity at the Round Table Congress of becoming a builder of a new India, in which there will be real partnership with Great Britain.

The tangled skein that was the legacy of the world war is gradually being smoothed out. The acceptance of the British Government's invitation to Dr. Bruning, the German Chancellor, and Dr. Curtius, the German Minister of Foreign Affairs, is assured, and is a happy augury of increased confidence between the two nations. The conditions in China are becoming normal, Indian affairs are less complicated than they were, the Austro-German Customs Union may be a purely economic agreement or a political matter, but instead of the hysteria it has created in some quarters, it should have the sympathetic understanding of all who believe that people have the right to rough-hew their own destinies. A finger may be pointed at Australia, and the cynic may suggest that there at least the progress is backward. Australia is a young country, with powers of recuperation that only a young country, rich in natural resources, possesses, and the default of New South Wales to meet its financial obligations has given the opportunity to the Commonwealth Government to make a gesture that will not soon be forgotten in England. Mr. Lang, the Premier of New South Wales, has been the unwilling and indirect instrument of strengthening the bonds of the Empire. It would be idle, of course, to state that this debt repudiation decision of the Lang Government has improved financial and commercial confidence in Australia. It will, in fact, tend, temporarily we hope, to prevent the promotion of industrial enterprise within its borders by British manufacturers, that recent inflationary proposals induced. Australia could profitably model itself on Canada, which is forging ahead, and is one of Britain's best customers.

The wonderful reception accorded to the Prince of Wales when he opened the Buenos Ayres Exhibition presages increased confidence. The results achieved since this Exhibition was opened prove the existence of possibilities far greater than was anticipated, and trade with the Argentine should increase very considerably in the near future. It is interesting to note that the Grand Council of the Federation of British Industries record their view that only the Prince of Wales in person could have rendered to British manufacturers that assistance which has given them the opportunity of increasing the trade and goodwill with the peoples of South America.

In spite of the activities of other countries to foster shipbuilding in their own shipyards by direct and indirect subsidies, by special freights, rebates, and similar devices, British shipyards are gradually increasing their former proportion of the world's output. Before the war more than half the world's total output of ships was built in British shipyards: this proportion was reduced to about a third after the war, but it is gratifying to note that our national advantages have gradually asserted themselves, and the figures for 1930 show that we have again been building more than half the world's ships.

Rationalisation of various industries has been in progress for some time, and is being tackled with commendable energy. The obstacles in reorganising the iron and steel industry, for instance, were very great, and while much remains to be done, the prospects of ultimate success are better now than at one time seemed possible. It must not be forgotten that reorganisation was undertaken in the throes of a world price slump, and manufacturers should be commended for their courage and their display of confidence in the ultimate restoration of normal trade.

The latest investigations by Mr. E. G. Herbert on Hardening Metals by Rotating Magnetic Fields, deals with Tool Steels and will be published in our May issue.

Exaggerated statements have been made from time to time in regard to the coal trade. Handicaps in actual technique do exist, but the best equipped mines do not suffer in comparison with those of other countries. The future use of coal will undoubtedly be a factor governing the future of the coal industry, and in this direction British research has made considerable headway, and has in many directions progressed farther than other countries. Recent investigations have shown that a ton of coal, treated by hydrogenation, will yield 130 gals. of spirit.

Britain's dependency on her export trade of manufactured goods has made her peculiarly vulnerable to obstacles such as high tariffs and currency chaos. The world's industrial demand has changed; in particular that for the staple British products has remained stationary or contracted. It must be remembered that the standard of life for the working people in Britain is higher than in Continental countries, and taxes on industry also are relatively higher, but in spite of these many handicaps, Britain has gone far in adapting her industrial life to the changing times. She has shown remarkable resilience in times of stress. Her industries are better organised, and, as a result of improved technique, they are producing at an increased rate.

The maintenance of the same degree of goodwill at home that is gradually being manifest abroad, will do much to dispel the hasty and superficial assumptions of a permanent decline of British prosperity and influence. There is every reason for greater optimism, and with it increased confidence, which assists very considerably in the restoration of normal industrial conditions. The fact that during the last few weeks the unemployment total has been reduced by over 100,000, while not as much as is desirable, is an indication that the worst of the depression has been passed.

Hardening Metals Magnetically.

THE internal mechanism of work-hardening of metals is not yet fully understood, but it is generally believed to be associated with the distorted space lattices adjacent to the slip planes, and the secondary hardening resulting from ageing. The discovery of remarkable changes in the space lattices of crystalline materials as a result of the action of a rotating magnetic field, referred to elsewhere in this issue, will readily find application in the treatment of hardened and super-hardened steel, and there is every likelihood of the process being applied to finished cutters and other tools to increase their hardness and cutting capacity. Besides increasing the hardness of steel by the process, it has been found that the hardness increase is maintained at high temperatures. It is not yet possible to foresee what further practical results may follow from changes in the existing properties of metals; perhaps new properties of an unknown character may be imparted to them by this process. It is by no means certain that the effects of the process are confined to metals.

A striking feature of this invention, which has been patented, is the effect of the magnetic process on metals usually regarded as non-magnetic—brass and duralumin,—an effect similar to that produced on steel. The phenomena are believed to be atomic in character, and their discovery should lead to an extension of knowledge in the realm of atomic physics.

The discovery of this process is the result of much experimental investigation by Mr. E. G. Herbert, and is the latest product of the "Pendulum Research." Many years have been devoted to investigations carried out with the Pendulum Hardness Tester, which has proved a valuable research instrument, and has revealed a series of phenomena not readily discoverable by other means.

In the direct line of the present results was the discovery that the hardest steel can be "superhardened" by rolling it with a spherical diamond, and that hard steel parts of motor-cars are superhardened by the severe abrasion which occurs in service. This led to the invention of the "cloud-burst" method of superhardening steel by bombarding it with hard steel balls; the discovery that superhardened steel undergoes a further spontaneous hardening during several hours after the cloudburst; and the invention of the magnetic process of rotating polarity to enhance this spontaneous increase of hardness. The discovery that the rotating magnetic field does not simply harden, but causes a sequence of hardness changes with time, led to its application to a variety of steels both hard and soft, and to non-magnetic metals. It is likely that further developments will follow.

Iron and Steel Institute.

THE annual meeting of the Iron and Steel Institute will be held at the Institution of Civil Engineers, Great George Street, Westminster, on Thursday and Friday, May 7 and 8, 1931. The newly elected President, Colonel Sir Charles Wright, Bart., K.B.E., C.B., will deliver the Presidential Address, and subsequently the following papers will be presented at the various sessions:—"The Sub-crystalline Structure of Ferrite," by C. O. Bannister and W. D. Jones; "The Formation of Ferrite from Austenite," by Sir H. C. H. Carpenter, F.R.S., and J. M. Robertson; "Refractory Materials for the Induction Furnace," by J. H. Chesters and W. J. Rees; "Production Economy in Iron and Steel Works," by O. Cromberg; "Blast-furnace Data and their Correlation—Part II.," by E. C. Evans, L. Reeve, and M. A. Vernon; "The Resistance of Copper-nickel Steels to Sea Action," by J. Newton Friend and W. West; "On the Nature of Defective Laminations in Wrought-iron Bars and China Links," by H. J. Gough and A. J. Murphy; "The Basic Process: Some Considerations of its Possibilities in England," by V. Harbord; "Some Alloys for Use at High Temperatures: Complex Iron-nickel Chromium Alloys—Part II."; "The Effect of Composition and Exposure to High Temperatures," by C. H. M. Jenkins and H. J. Tapsell; "The Effect of Carbon and Silicon on the Growth and Scaling of Grey Cast Iron," by A. L. Norbury and E. Morgan; "X-ray Investigations on the Crystal Structure of Hardened Steel," by E. Ohman; "The Constitution of Scale," by L. B. Pfeil; "X-ray Investigation of Certain Nickel Steels of Low-thermal Expansion," by G. Phragmer; "The Melting Shop of the Appleby Iron Co., Ltd.," by A. Robinson; and "Accelerated Cracking of Mild Steel (Boiler plate) Under Repeated Bending," by W. Rosenhain, F.R.S., and A. J. Murphy.

Forthcoming Meetings

ROYAL SOCIETY OF ARTS.

April 29. "Stainless Metals" by Sir Harold Carpenter, M.A., Ph.D., F.R.S.

INSTITUTION OF MECHANICAL ENGINEERS.

April 17. General Meeting. "Post-war Land Turbine Development," by C. D. Gibb, B.Eng.

May 1. Discussion on "Hydraulic Valves," introduced by Henry Crowe.

INSTITUTION OF MARINE ENGINEERS.

May 12. "Low Cost Motorships," by Mr. O. E. Jorgensen.

IRON AND STEEL INSTITUTE.

May 7 & 8. Annual Meeting, at the Institution of Civil Engineers, Great George Street, London, S.W. 1.

May 7. Annual Dinner, at the Connaught Rooms, Great Queen Street, London, W.C. 2, at 7 for 7-30 p.m.

May 11. Middlesbrough Branch. Papers: "Production Economy in Iron and Steel Works," by O. Cromberg, and "The Melting Shop of the Appleby Iron Co., Ltd.," by A. Robinson. At the Cleveland Technical Institute, Corporation Street, at 7-30 p.m.

May 14. Birmingham Branch. Papers: "First Report on the Corrosion of Iron and Steel" (this is a report by a Joint Committee of the Iron and Steel Institute and the National Federation of Iron and Steel Manufacturers to the Iron and Steel Industrial Research Council); "Production Economy in Iron and Steel Works," by O. Cromberg; "On the Nature of Defective Laminations in Wrought-iron Bars and Chain Links," by H. J. Gough and A. J. Murphy; and "The Melting Shop of the Appleby Iron Co., Ltd.," by A. Robinson. At the Birmingham Chamber of Commerce, 95, New Street, at 7 p.m.

INSTITUTE OF METALS.

April 17. Sheffield Section. "Extrusion," by R. Genders, M.B.E., M.Met.

May 6. General Meeting. Annual May Lecture. "The Progress of Power Production" by William B. Woodhouse, M.Inst.,C.E.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

April 17. "Corrosion of Oil Tankers," by J. Foster King, C.B.E., Chief Surveyor, British Corporation Register of Shipping and Aircraft.

INSTITUTE OF BRITISH FOUNDRYMEN.

April 16. London Branch. Annual General Meeting.

April 17. Sheffield Branch. (1) Annual Meeting and Election of Officers. (2) "The Use of Oil in Cupola Practice," by J. R. Hyde. Stoke-on-Trent.

April 23. Birmingham Branch. (1) Annual General Meeting. (2) General Discussion.

April 25. Newcastle-on-Tyne Branch. (1) Annual General Meeting. (2) General Discussion on Foundry Problems.

April 25. West Riding of Yorkshire Branch. Annual General Meeting.

May 2. Lancashire Branch. "The Manufacture of Large Marine Propeller Castings," by Wesley Lambert, C.B.E., London.

ELECTROPLATERS' AND DEPOSITORS' TECHNICAL SOCIETY.

May 13. "Problems in Chromium Plating and High-current Density Nickel Plating," by N. R. Laban, B.Sc.

Correspondence.

The Editor, Metallurgia.

Dear Sir,—We have read with interest the articles on "The New Alloys and Machine Tool Design" appearing in Metallurgia.

We should like, as the makers of Stellite, to draw attention to the Fig. 2 on page 92, and the accompanying description, which states that such a tool is made by building-up the tip with welding rod. This practice is quite incorrect, and is likely to lead to disappointment. Cutting edges should not be built up, but the tool should be made by brazing a solid piece of Stellite on to the shank. A built-up tool will not have the cutting efficiency of a brazed tip tool.

We notice also that the price of Stellite is given as about £1 per lb. The price is actually 18s., and as an allowance is made for scrap returned, it works out at considerably less.

Finally, we can assure you that the changes which have been made in the composition of Stellite are not accidental, but the result of careful experiment. Stellite to-day consists of cobalt, chromium, and tungsten, and does not contain molybdenum, manganese, or silicon.

We should be glad if you would give the same prominence to these corrections as was given to the original article.—Yours faithfully,

Deloro Smelting and Refining Co., Ltd.
F. W. P. Hulme.

The Editor, Metallurgia.

Dear Sir,—I am sorry if from Messrs. Deloro Smelting and Refining Co.'s booklet, "Directions for Stelliting," in which appear illustrations of twist-drills, fish-tail bits, hammers, dies, dredger dipper, and cutter teeth, all "built-up" by the Stelliting process, I have been misled into stating that the same process was applicable to some tools of the lathe type. I am aware, and I stated, that such tools were also prepared by brazing on to shanks tips of Stellite.

Concerning the remainder of the "corrections," to which you are asked to give prominence, I submit that there is nothing to correct, for the concerned portion of my articles dealt not with the present, but with that time in which, if one may judge from published analyses, Stellite was in process of development. Your correspondents, too, admit, by implication, that Stellite is not the same now as then.

That some samples did contain molybdenum, manganese, and silicon is proved by analyses made by the U.S.A. Bureau of Mines in or about 1920, and that the contents varied considerably by the prolonged investigation of the Manchester Association of Engineers, as reported in its "Transactions for 1914-15."

I believe that my articles must leave the impression I certainly intended to convey in the words, "Stellite, much improved, is a material which, at the moment, ranks high as a metal remover," that Stellite to-day is better than Stellite yesterday.

Concerning the price, my words were: "It *cost* about £1 a pound against 4s. for high-speed steel," both figures referring to the period of development, not to the present time. Even had I said "costs," I think I can scarcely be convicted of error, for 18s. is really not far short of £1. My experience has been that so little is left of Stellite, properly applied, that one can count as its cost the money paid for it.—Yours faithfully,

Heywood, Lancs. Francis W. Shaw.

[Considerable progress has been made in the production of Stellite since the earlier days to which our contributor referred. To-day, there can be no question that the strictest control is exercised over the nature and purity of its components, as well as the method of manufacture, resulting in a product of unvarying quality, which, together with its known high cutting properties, is responsible for the increasing application of Stellite to meet modern conditions.—Editor.]

Injection, Ignition, and Combustion in High-speed Heavy-oil Engines.

It is questionable whether the present rapid development of high-speed heavy-oil engines would have taken place if a high-pressure air-compressor had been an essential accessory. It is perhaps well to emphasise that from the beginning designers of engines of the pure "compression-ignition" type have striven after airless injection of the fuel, and it is interesting to note that, as late as 1920, almost all experiences with airless injection had been gained in this country.

A consideration of the problems met with in high-speed heavy-oil engines indicates why successful airless injection has only progressed slowly. Assuming that the engine must be flexible both as regards speed and load, these problems include the metering of the fuel to the engine in the correct quantities at all desired speeds and loads; the delivery of the fuel into the cylinder under these conditions at a suitable pressure and at such a rate that combustion may proceed, so that, on the one hand, it is complete at a point in the expansion stroke sufficiently early to ensure good thermal efficiency, and that, on the other hand, the rise of pressure behind the piston is neither irregular nor too sudden, conditions which would cause "roughness" in running; the suitable subdivision or atomisation of the fuel, and the suitable control of its direction and penetration; and the control of the motion of the air in the cylinder, so that the mixing of fuel and air may lead also to satisfactory rates of combustion.

The present state of knowledge was discussed in a paper delivered recently before a joint meeting of eleven Societies, at the Institution of Mechanical Engineers, by Messrs. S. J. Davies, Ph.D., M.Sc., and E. Giffen, M.Sc., in which the subject was subdivided roughly under two headings—processes in the fuel-injection system, and processes within the cylinder. Under the former the conditions in the pumps, connections, and nozzles, the actions of which are all mechanical in character, were considered. The latter heading embraced the mixing together of the fuel and air, the ignition of the fuel, the complete combustion of the fuel, and the resulting change of pressure and temperature in the working substance.

The authors compared the present state of development of the high-speed heavy-oil engine, particularly in its diversity of form, to that of the petrol engine of twenty-five years ago. In the interval the petrol engine has reached a more or less standard form, and a vast volume of experience has been gained. Successful competition by the heavy-oil engine will, they assert, only be possible by careful investigation of all matters affecting its performance, and they suggested points upon which fuller knowledge is urgently needed. These included ignition lag and how it is influenced by rate of fuel injection—*i.e.*, by the fuel pumps, nozzles, and systems; by regulated movement of the air; by cylinder design; and by various fuels. Fuels and their physical characteristics—namely, data of a similar nature to those concerning petrol engine fuels made available by the work of Ricardo, Tizard, Pye, and others. Especially in regard to ignition lag is co-operative action essential. In view of the extremely valuable results obtained by the Marine Oil Engine Trials Committee, the authors suggest similar co-operation, through the technical institutions, by the firms producing high-speed heavy-oil engines.

S.O.S.

The demand for recent issues of "Metallurgia" has been so great that many issues are now out of print. Requests are continually being received for certain issues to make up volumes, and we would esteem it a favour if any of our readers, who have finished with their copies, are willing to dispose of them. We particularly desire the issues of January, April, June, August, September, October, and November, of 1930.

The New Alloys and—— Machine-tool Design

By Francis W. Shaw, M.I.P.E.

Part IV.—Hand-actuated Work-holding Devices.

The problems that confront the designer of modern work-holding devices are examined. The desiderata in such devices are indicated.

WE have explained how, whilst on large work modern cutting materials, permitting higher cutting speeds and feeds than the older steels can vastly influence the output, their effect rapidly diminishes as the size of the work falls and its complexity rises, unless they induce improvements in machine tools and equipment, in methods and in the processes of production; the implication being that, in the absence of such improvements, not only would further betterment of cutting materials be futile, but even those already made could scarcely be justified, for their effect on the bulk of the work of the average machine shop would be so small as to go almost unnoticed. And that is why so much attention is now being given to factors that control the

Fig. 18.—Phantom View of Taylor "Spiral" Chuck.

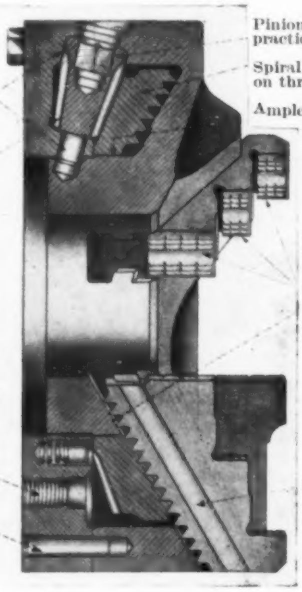

Fig. 19.—Section of Taylor "Spiral" Chuck, illustrating its construction.

non-cut-time factors, which in our last instalment were divided into two groups—group (*a*), those applying to a run of work and divisible by the number of pieces in the run, and group (*b*), those chargeable to each work-piece.

It is convenient now to study factors (*b*), the first of which, the chucking factor, if not the predominant factor, comprising inserting, securing, and removing the work-piece, is that to which, perhaps, the most thought has recently been given for the reason that it constitutes the most difficult problem confronting the designer of machine tools or of their equipment.

The Chucking Factor.

The problems chucking presents are many, varying with the work-piece and the operation. In chucking devices many important and interesting improvements have already been witnessed. The desiderata, in every such device, are: (1) It should grip without permitting slip; (2) it should not appreciably distort the object; (3) it should not yield in itself sufficiently to mislocate the object; (4) it should not tend to relax its grip when the cut is applied; (5) it should accurately locate the object in relation to the axis of rotation or to already machined surfaces and to the tools; (6) it should be as efficient in action as the type of the operating mechanism permits; (7) permanent parts liable to break or subject to rapid wear should be readily and cheaply renewable; (8) special or changeable parts, such as chuck jaws, should be renewable by the owner or user at the least possible cost—simplicity should be the keynote of design; (9) It should be capable of being actuated by one hand, or by foot if both hands are needed to hold the object, or be entirely automatic; (10) its working parts should be inaccessible to dirt, cuttings, and coolant; (11) the gripping and locating elements should be easily cleansable; (12) it should carry its own actuating mechanism, unless this is embodied in the machine; (13) it should not hamper the insertion or the removal of the object; (14) it should not overhang from its support or base more than construction permits or the shape of the objects necessitates; (15) if a rotating device, it should be in dynamic balance in itself, or with the work-piece if special to the piece; (16) to actuate it should not fatigue the operator; (17) it should provide for the operator's safety; (18) provision should be made to intercept splash of coolant and flying cuttings; (19) it should be provided with means for conducting the coolant to the cutters and away, along with the cuttings; (20) it should be easy to install and remove; (21) it should be interchangeable with other chucking devices; (22) its working parts should be easy to lubricate or automatically lubricated, and provision should be made to retain the lubricant.

Screw and Scroll Chucks.

Turning being the major process in most machine shops of work-holding devices, lathe chucks naturally fall first for review. For many purposes ordinary screw- and scroll-actuated chucks are to be preferred, but, regrettably, in construction, ease of operation, and efficiency, they leave much to be desired. Yet both types are capable of being vastly improved by very slight modifications in their general structure.

So far as our information carries us, improvements intended to strengthen the chucks sufficiently to meet or partially to meet modern demands have taken the obvious direction of increasing the strength of the weaker elements. The body, for instance, is now frequently made of semi-steel (so termed, though erroneously), cast steel and forged steel; the pinions in scroll chucks of alloy steels, heat-treated, the scrolls hardened. And utterly ignored, if not forgotten, has been the possibility of increasing the accuracy, life, and durability by improving the efficiency of the mechanism.

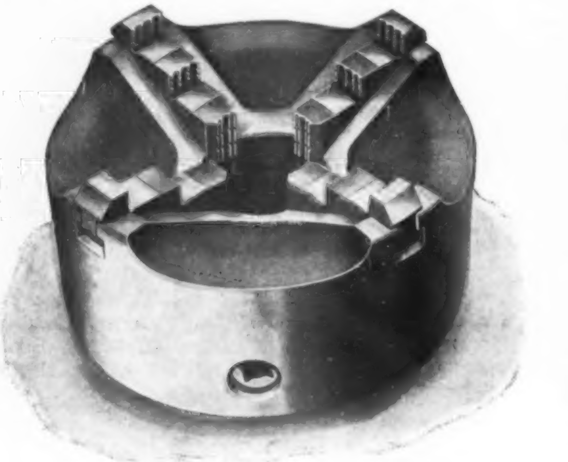

Fig. 20.—The Taylor "Spiral" 4-Jaw Bar Chuck.

Whilst we know of attempts along the suggested lines, we do not know of an existent chuck exhibiting fruition of the attempts. Rather has development proceeded in the direction of wholesale structural modifications, many of which, we feel, would never have been made if more study had been given to the simple mechanical principles involved.

Is it generally realised, we wonder, that the principle upon which most lathe chucks depend for multiplication of effort is that of the wedge? For the threads of screws and scrolls are but wedges coiled around cylinders or spirally on planes. And the wedge, investigation will reveal, is a most inefficient, if not the most inefficient, mechanical device, particularly if it be made self-sustaining or self-locking—the more usual term,—or, in other words, if the angle of repose is as small as it customarily is.

Now, if we study the efficiency curve of the screw or scroll "wedge" as this is embodied in screw and scroll chucks, we shall immediately realise how vast an influence would have the mere increasing of the wedge angle, easily accomplished by replacing single-threaded screws by double-threaded screws, and by increasing either the pitch or the lead of scrolls.

In few screw-actuated chucks does the thread angle of the screws exceed 5°, and in scroll chucks the scroll thread angle exceed 1°. Where the angle is small the efficiency increases almost directly as the wedge angle. Hence, the mere doubling of the number of threads in the screw or scroll would nearly double the efficiency; trebling the number would nearly treble the efficiency. If, then, the efficiency of all the friction-producing elements could likewise be increased, the effort required to grip the work would be reduced proportionately. Or, alternatively, if the chuck be strengthened, the grip could be proportionately increased. A little study will convince that this is not an impossibility; we need but allude to the possibility of reducing the coefficient of friction that would follow hardening and grinding and polishing all the friction-producing surfaces, and wherever possible increasing their area so as better to resist without abrasion the heavy pressures to which they are naturally subjected in heavy gripping. Better means for lubricating and for excluding dust and cuttings, too, would help in the same direction. With these improvements the chucks would favourably compete in efficiency with the more costly of the modern chucks, whose increased gripping power is due more to attention to basic mechanical principles than to new features of construction.

The foregoing analysis bears on several of the enumerated factors, but more particularly upon the fatigue factor, for, notoriously, to chuck heavy work-pieces or work-pieces for heavy cuts makes heavy demands upon the operator—demands which are most severely felt at the work-day end.

Taylor "Spiral" Chuck.

Perhaps the earliest realisation of the defects of ordinary scroll chucks was by Charles Taylor (Birmingham), Ltd.—realisation expressed in the firm's "Spiral" chuck, a phantom view of one of which Fig. 18 presents.

In this chuck the jaws slide in ways inclined to the axis of the chuck, and the teeth on the rear surfaces of the jaws mesh with the thread of an internally-conical scroll. By this arrangement a portion of the pressure that in ordinary chucks is borne by the jaw-ways falls on the scroll threads better adapted to receive it, for the threads are hardened and ground (in most scroll chucks the scroll is soft and grinding is not praticable). The construction of the chuck will be clear from Fig. 19. As the jaws move inwards it will be seen they also move in the direction of the axis, so that, for a given total movement along the ways, the inward movement of the jaws is somewhat less than in the ordinary scroll chuck, and, as a consequence, the purchase is also greater.

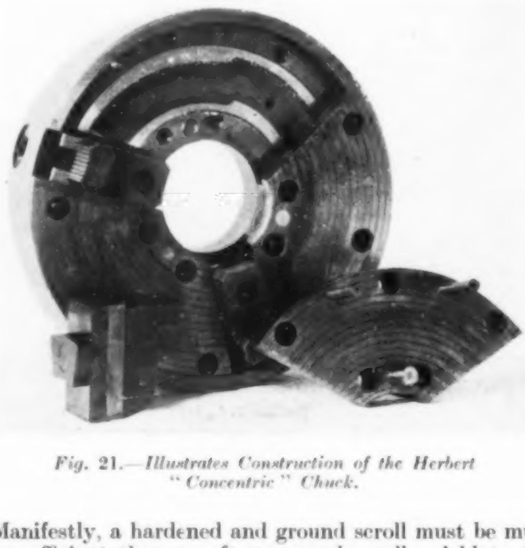

Fig. 21.—Illustrates Construction of the Herbert "Concentric" Chuck.

Manifestly, a hardened and ground scroll must be much more efficient than a soft unground scroll. Add to this improvement that effected by the reduction of pressure on the jaw-ways, and we see immediately that the efficiency must be several times as large as in the ordinary scroll chuck as at present it is.

The efficiency increase naturally signifies that more of the applied effort reaches the work-piece, and if so, the reaction upon the chuck must be more severe. Fortunately, these very structural features which have brought about increased efficiency have introduced means to resist the increased reactionary forces. The scroll and its threads are

stronger, and as the jaw-ways do not extend so deeply at their outer extremities into the chuck body, this again is stronger at those very points at which fracture usually starts.

Those who are familiar with the process of turning pieces extending from the jaws of a three-jaw chuck may have noticed that the work tends to flinch more where it is supported by the jaws than where it is not supported, and when the cuts are heavy the work is at times a little out of round—somewhat trilobate in fact, the trilobate effect gradually lessening as the tool approaches the body of the chuck. With a four-jaw chuck, as that illustrated by Fig. 20, the lobate (it would be quadrilobate) effect is practically eliminated. The use of such a chuck is, of course, restricted to round or square bars of fairly uniform diameter, and to individual pieces comparatively circular. For delicate pieces, tubular, for instance, a multi-jawed chuck is advantageous for, whilst the total gripping pressure can be all that is needed to hold the piece firmly, the local pressure is reduced and the distorting effect, therefore, lessened.

How others of our "desiderata" are met the wording on Fig. 19 clarifies.

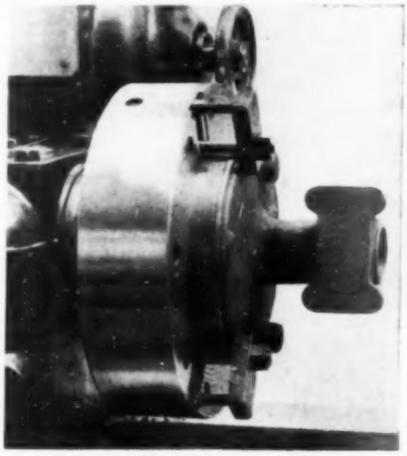

Fig. 23.—Herbert "Concentric" Chuck, its jaws removed, forms an effective face-plate.

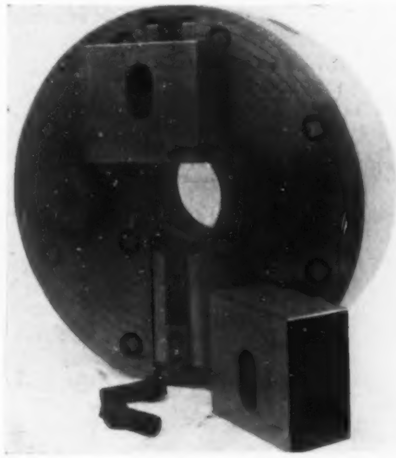

Fig. 24.—Herbert 2-jaw "Concentric" Chuck, here shown with soft rectangular jaws which can be shaped to conform with the outline of the work-piece.

Herbert "Concentric" Chuck.

How the problem of increasing the efficiency of scroll chucks has been solved by Alfred Herbert, Ltd., can best be illustrated by reference to Fig. 21.

As in the screw, the efficiency of a scroll depends upon, increasing with, the wedge angle. In this chuck the usual threads are replaced by a wide groove with highly-polished acting surfaces, the three sections of the groove being formed as circular arcs (not as spiral curves) struck from three equi-spaced centres near the axes of the chuck. Hardened and polished shoes, pivoted to the serrated jaw carriers, fitting the cam groove, compel the jaws to slide when the cam is turned with the chuck lever.

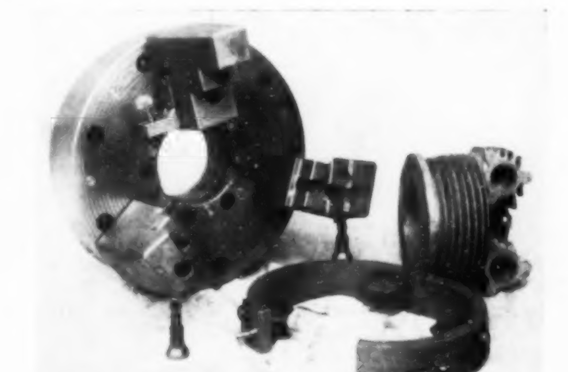

Fig. 22.—Herbert "Concentric" Chuck, provided with special jaws and a clamping ring adapted to hold a Cylinder-Head.

The "rise" of these "cam" arcs in about a third of a circle is about that of an ordinary scroll in a full turn. From our recent analysis it follows, then, that given equal materials, the efficiency of this "arc" scroll must be nearly three times that of an ordinary scroll ot the same dimensions. Hardened and ground sliding surfaces and better lubrication should help to maintain the efficiency increase throughout the mechanism. If this really follows, it is clear that three times the grip will ensue from a given expenditure of energy.

Of these chucks, Messrs. Herbert claim that not a single body do they know to have broken in service, though the body is but of cast iron, densened, it is true. Undoubtedly, for this is responsible the absence of jaw-ways breaking the continuity of the periphery.

From Fig. 22 to 24 it will be seen that the chuck is something more than a chuck—it forms, indeed, a universal holding device. Fig. 22 depicts how an awkwardly-shaped cylinder-head is located and gripped firmly enough to withstand the heavy cuts imposed by wide form tools used in finishing the bottom of the bore. Chucking is through a carrier ring surrounding the work-piece, the ring being hinged to permit of its being opened to allow the grip fingers to be inserted between the fins. These fingers are free to float in all directions to conform to irregularities in the surfaces of the work-piece and centralise the piece by its walls, so ensuring an even thickness of metal about the bore. As a grip just sufficient to hold the piece without distortion will not resist the stresses tending to rotate the piece within the ring, the piece is prevented from turning by an adjustable knurled-headed screw, seen fitted to a bracket attached to the uppermost jaw, the screw impinging against one of the port faces of the cylinder-head.

Fig. 23 shows how, the jaws removed, the chuck forms an effective faceplate, obviating the waste of time that would accompany necessity to replace the chuck by a faceplate. Here the work-piece is centralised by a spigoted ring or adaptor, the nuts which ordinarily receive the jaw screws now accommodating the clamp screws.

Fig. 24 illustrates the two-jaw variety of the "concentric" chuck. Fitted with a pair of veed jaws, it makes a powerful bar chuck. Work-pieces of "uncouth" shape are held by special jaws, soft or hard, cut to conform to the outline of the pieces. It can form the basis of many a useful fixture or jig, not only for the lathe, but for other machine tools. Any such special jaws or appliances can be removed from the serrated carriers, stored away, and replaced at any time with the certainty that they will locate the work-pieces with accuracy.

Forkardt "Wedge" Chuck.

The principle of the wedge, obscured in screws and scrolls, is visibly present in the mechanism of the Forkardt chuck "phantomed" by Fig. 25, from which the action will be transparent (as well as the body).

The makers' claim for exceedingly high efficiency an analysis of the action would seem to justify, as it would

justify our expressed opinion that the ordinary scroll chuck could be improved by stricter attention to mechanical principles.

Now, as we have indicated, the inefficiency of scrolls is due to the smallness of the wedge angle. Whilst this could be considerably increased, the increase is limited to some angle about 8°, this being a little higher than the angle of repose of hard smooth lubricated surfaces, for the reason that little resistance is afforded by the bevel gear and actuating pinions, this type of gearing being highly efficient. To employ even the angle of 8° might be risky, for, the resistance being small, the scroll might turn under vibration. The total efficiency must, indeed, be well below 50%, the point at which the resistance, frictional, equals the force reacting from gripping.

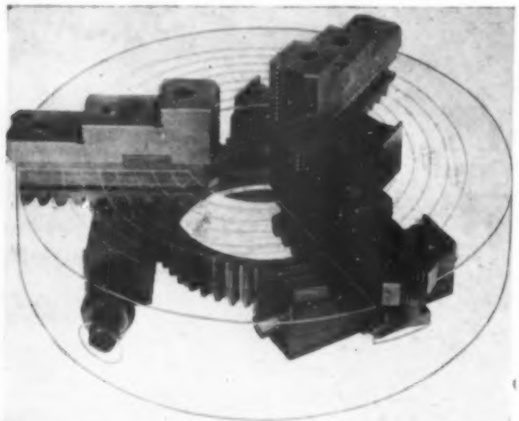

Fig. 25.—Phantom View of Forkardt "Wedge" Chuck.

In the Forkardt chuck the wedge angle is about 15°, an angle at which hard smooth surfaces easily slip upon one another. The wedge portion of the mechanism, therefore, is not self-locking, and dependence must consequently be had from other elements to prevent the jaws backing. These other elements take the form of a screw and nut, the nut being part of one of the wedge racks, all of which are restrained from end movement by the one screw by reason of their being connected by the toothed ring.

It is the transference of the frictional resistance from highly stressed members to members less severely stressed that accounts for the chuck's high efficiency, hence easy actuation.

A time-saving feature of this chuck is due to the provision made for removing the jaws bodily. They can be removed after the wedges are slid in one direction just far enough to disengage the wedge teeth from the jaw teeth. This is the means adopted, too, for adjusting the jaws from one diameter to another. Ordinarily, however, the upper portions only of the jaws would be removed for replacement by others.

(*To be continued.*)

Recent British Standard Specifications.

THE British Engineering Standards Association have just issued Specifications for "low carbon" steel cylinders for the storage and transport of "permanent" gases, and for steel cylinders for the storage and transport of "liquefiable" gases. These Specifications are based on the summary of recommendations for the storage and transport of liquefiable and "permanent" gases included in the first and fourth reports of the Gas Cylinders Research Committee of the Department of Scientific and Industrial Research.

The "Low Carbon" Steel Cylinder Specification (No. 400) has been prepared for the storage and transport of such gases as atmospheric air, oxygen, nitrogen, hydrogen, etc., which, at the working temperature and maximum working pressure of 120 atmospheres, remain in a gaseous state in the cylinder.

The "Liquefiable" Gas Cylinder Specification (No. 401) has been prepared for the storage and transport of such gases as sulphur dioxide, ammonia, chlorine, methyl chloride, ethyl chloride, hydrocyanic acid, phosgene, carbon dioxide, nitrous oxide, ethylene, etc., which have relatively high critical temperatures, and which are generally reduced to the liquid condition by the pressures used in charging them into the cylinders.

The Specifications include particulars of tensile, impact, flattening, and hydraulic stretch and pressure tests, together with a formula for the determination of the minimum thickness of cylinder walls. These, together with the one issued in October of last year for "High Carbon" Steel Cylinders for the Storage and Transport of Permanent Gases (B.S.S. No. 399), complete the series of gas cylinder specifications which have been prepared by the Association.

B.S.S. for Valve Fittings for Compressed Gas Cylinders (No. 341). This Specification, which has just been issued, provides for valve fittings for compression gas cylinders for practically all the gases in general use, and requirements have been included for a safety release for carbon dioxide cylinders. Particulars are given in an appendix to the Specification of inspection gauges for checking the threads on the valves and the threads in the cylinder necks, and the National Physical Laboratory are the custodians of the standard gauges, so that the working gauges necessary for the production of cylinders and valves can be checked at a reasonable cost.

B.S.S. for Identification Colours for Gas Cylinders (No. 349). This Specification provides for identification colours for gas cylinders for gases most commonly in use, the underlying principle of the scheme being that yellow should represent toxic or poisonous gases, and red or maroon inflammable gases—for example, hydrogen and coal-gas cylinders are to be coloured red, chlorine cylinders are to be coloured yellow; and the colour of cylinders for carbon monoxide—an inflammable and a very poisonous gas—is a yellow ground with a red band.

The Committee responsible for the preparation of the schedule has recognised that there are other gases used in limited quantities, for which a colour has not yet been allocated, and they point out that it is important that the colours so far adopted should not be used for gases other than those indicated.

Two further specifications for non-ferrous sheets and strips have recently been issued by the British Engineering Standards Association. These are No. 407 Phosphor Bronze Sheets and Strip (excluding drawn material), and No. 409, Naval Brass Plates, Sheets and Strip (excluding naval brass condenser plates).

The first specification covers two alloys, high tin and low tin, respectively, each in five tempers, the tensile strengths ranging from 18 to 43 tons per sq. in. The second specification provides for both hot-rolled and cold-rolled material of tensile strengths from 22 to 26 tons per sq. in.

Both specifications call for tensile and bend tests, whilst a forging test is also stipulated in the case of the naval brass. The chemical compositions and the tolerances to be permitted on the dimensions of the sheets are specified, and clauses relating to the provision of test-pieces and testing facilities are included.

Copies of the above Specifications (Nos. 400, 401, 341, 349, 407, and 409, 1931) can be obtained from the Publications Department, British Engineering Standards Association, 28, Victoria Street, London, S.W. 1, price 2s. 2d. *each*, post free.

Copper Production in Canada.

Recent returns of the International Nickel Co. of Canada Ltd., indicate that Canada is taking a prominent position in the world's copper industry. This company can produce 90,000 tons of nickel and 120,000 tons of copper per year. An important by-product of the nickel operations is the platinum metals for which the company has a refining capacity of 300,000 ounces per year at extremely low costs.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part VI.–Ingot Moulds.*

The various types of moulds used in casting aluminium rolling ingots are discussed in this article.

It was emphasised in the first part of this article that methods of mounting moulds vary considerably. Moulds of the vertical, stationary type, may be mounted in the same manner as was described for the flat, open moulds. In one plant vertical, stationary moulds, positioned with the width axis upright, are mounted on small buggies which run on a track. About five moulds are placed on the bed of each buggy, and the moulds are poured directly from a stationary-hearth furnace.

Tilting, vertical book moulds may be hung from a horizontal bar by means of a lug situated at the top, as indicated in the previous discussion, or may be pivoted on trunnions situated at the centre of gravity of the mould. The former method appears to be preferable, since the mould can be opened and the ingot removed more rapidly. Centrally pivoted moulds are employed in European practice, but are not favoured in the United States. Pivoting at the top, incidentally, reduces the arc traversed by the pouring edge of the mould. A mould-tilting machine is described by Rosenhain, Archbutt, and Hanson.[1] In this the mould is centrally pivoted and held by blocks. Tilting is by hand-wheel. Centrally pivoted moulds may be tilted by hand-lever.

In mass-production practice, using tilting, vertical book moulds, it is essential that the mountings and fittings should lend themselves to easy and fast operation. This means that the set-up should be conducive to rapid opening and closing of the mould and quick removal of the ingot. Moulds of the type shown in Figs. 4 and 5 are tilted (raised and lowered) by means of hoists. A bolt eye is inserted in the front edge of the mould for attaching the hoist hook (*cf.* Figs. 6 and 7). Manually operated chain hoists for raising and lowering the mould have been found unsatisfactory—the descent is prone to be jerky. Electrically operated hoists, having variable speed ranges both up and down, yield highly satisfactory results. Such hoists may be provided with automatic cut-off stops which limit the height in raising and the descent in lowering. Hydraulic tilting mechanism has been applied to book moulds.

Fit of the suspension lug on the horizontal supporting bar should be snug, but there must be no binding. A sloppy fit causes wobbling of the mould in lowering. Suitable floor plate should be provided beneath the mould, so that when it has been lowered it stands level and in a vertical position.

The means or device used for locking the mould sections has important bearing on the ease of operation and on maintenance costs. The use of clamps or bands and wedges, in the writer's opinion, is ridiculous, and the bolt-and-spring method previously illustrated in the drawing of Fig. 4 is not any too good. Any method of fastening which requires battering of the fittings with heavy sledge hammers is undesirable—the operation is slow and cost of repairs is high. Locking cams of the type shown in a previous drawing, Fig. 5, have been found very satisfactory in the writer's practice. These locks consist of steel brackets and eccentric spools. They may be used with or without springs. Such cams draw the halves tightly together and hold firmly in position ; they can be knocked open with a light blow. In some designs of moulds the halves are held together at the front edge with only one keeper. It is believed that more satisfactory results are had with two—one situated towards the top and the other towards the bottom of the edge face.

Hinges present numerous points of interest, but these cannot be dealt with in detail here. Those illustrated in the first part of this article have been found satisfactory, but other variations in design are also suitable. Hinge halves and bars should be amply heavy, the design should be simple, and fancy gadgets which easily get out of order should be avoided. This also applies to locking mechanism. When hinges are not cast integral with the mould, they may be made of steel (rather than cast iron), and bolted on.

Fig. 6. Tilting, vertical book mould, closed.

In an adaptation of the Durville process, the pouring ladle is affixed to the mould. The connection is made by means of hooks on the ladle, these hooks passing over pins set at right-angles to the mould side walls and threaded into small ears (cast integral with the mould).

Fig. 8 shows a leg or stand used for supporting tilting, vertical book moulds of the type illustrated in Figs. 6 and 7. A mould is hung from a horizontal bar, this bar being supported by two legs. The bar is held in position by the cap. In production set-ups, a line of ten or more moulds may be arranged on these legs, one more leg being required than the total number of moulds in the line, since each leg, except the end units, serves as a support for a bar on either side. A mould line-up has been shown in Fig. 2 of a previous article[12] of this series. Other views will be shown in the next article (dealing with the pouring of ingots), where the operation of ingot moulds will be considered. Leg stands may be made of grey cast iron.

Composition of Moulds.

Ingot moulds are usually made of grey cast iron, but there has been a tendency of late years to try alloy cast irons,

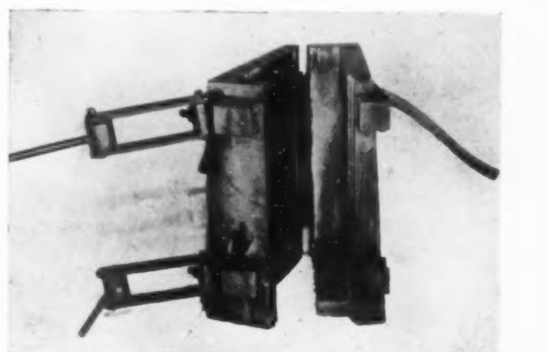

Fig. 7. Tilting, vertical book mould, open.

chiefly those of the nickel and nickel-chromium types. Carbon steel has also been used for moulds. Ordinary grey cast iron of the usual composition is a satisfactory material for moulds, and so-called semi-steel mixtures have given good results.

* *Continued from page 175 in last issue.*

Of late years much has been heard from alloy cast-iron propagandists about the importance of composition, and more especially regarding the effect of alloying elements, with respect to mould life. Although the composition of the iron undoubtedly has considerable influence on the life of an ingot mould and its performance in service, there are also various other factors which have as much or more influence. Hence, it is not safe to generalise too broadly and say that an alloy cast-iron mould will necessarily remain in active service considerably longer than a mould made of ordinary grey cast iron. One important factor affecting the life of a mould is the quality of the casting—*i.e.*, as regards soundness and freedom from cracks, porosity, inclusions, and other initial defects. A fine-grained and dense iron has longer life and yields better surfaces on machining than an open-grained iron. Generally speaking, if flaws are revealed in the mould faces on machining, the castings should be thrown out, since such flaws are likely to give trouble, sooner or later, in the production of ingots.

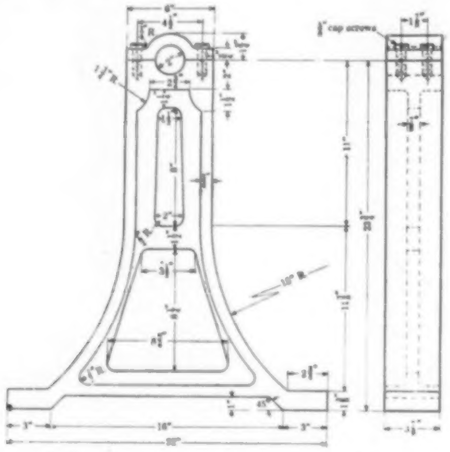

Fig. 8. Stand used for supporting tilting vertical book moulds.

Small cracks, for example, have a tendency to open up and enlarge on repeated heating and cooling of the mould. Poor surfaces result on pouring ingots into moulds having cracked or scarred faces. Erosion appears to set in at points where flaws exist in the faces—*e.g.*, in areas containing included non-metallic matter or porosity. As a general rule, it is not advisable to repair flaws, such as blow-holes or cracks, in mould faces by welding. Needless to say, perhaps, moulds should not be machined by the founder who furnishes the rough castings, but the machining should be done in the rolling-mill shop, where the work may be closely inspected by the melting-room foreman and the mill metallurgist.

Aside from ordinary grey cast iron for moulds, the use of nickel-chromium cast iron has been found to give good results in the writer's practice. That alloy cast irons are worth the extra cost has, however, not been demonstrated to the satisfaction of most operators. Alloy cast-iron moulds fail on account of surface checking and cracking (due to thermal fatigue) in the same way as ordinary moulds. It appears, however, that the onset of surface checking is deferred by the presence of nickel and chromium in the iron. One composition used for moulds is made by adding about 1·25% nickel and 0·7% chromium to ordinary foundry iron (2·25% silicon). Another composition consists of 25% Mayari pig iron, 25% medium steel scrap, and 50% Bessemer pig iron; the latter iron should be of the grade containing about 2% silicon and 0·9% manganese, with sulphur and phosphorus low; the Mayari iron should be of the grade which contains 1·5 to 1·75% silicon and 1 to 1·25% manganese (with nickel and chromium normal).

Permanent growth, due to repeated heating and cooling, is not serious in the operation of cast-iron moulds in aluminium practice. Although moulds do warp and distort somewhat with continued use, ordinarily the life of a mould is ended with the onset of surface checking.

Some operators claim that rough castings for mould should be "seasoned" before machining by standing in the open air exposed to the weather for a few months. The writer has been unable to find that this treatment has any effect on mould life or performance in service. Internal casting strains in rough blocks may, of course, be removed by annealing before machining or after machining off the skin of the inside wall, the tooling to finish being subsequently completed.

In passing, it is of interest to point out that in an emergency—*e.g.*, when a few ingots of special size, for which no moulds exist, are required, a mould may be made by clamping aluminium slabs together.

Mould Surfaces: Washes and Coatings.

The condition of the mould faces (internal walls) is important in relation to the surface finish on the ingots. For the best results in rolling, it is necessary to start with an ingot having smooth surfaces, free from contraction depressions, air traps, local roughness, or cracks. The writer favours the use of moulds having polished faces. In machining the inside walls before polishing, the final cuts of the planer should be very light. Polishing may be done with a portable buffing wheel. Parenthetically, it may be added that better surface finish is obtained when aluminium-alloy castings are poured in permanent moulds having polished faces as contrasted with unpolished faces.

Some operators claim that the internal wall faces of the mould should not be too smooth. Thus, it is stated that the striated lines (tool marks) left in planing are advantageous in promoting the escape of air from the mould as the metal is being poured, and that, therefore, the ingot surfaces are smoother than if poured in a mould having a smooth (polished) surface. Ordinarily, it is to be expected that the ingot will take any impression in the mould face, so that ingots poured in moulds having tooling marks will exhibit those marks.

The coating or oiling of mould faces to prevent the liquid metal from "burning in" or sticking is not necessary in aluminium work. However, in some plants (notably in Europe and Japan), it has been practice to coat the mould faces with lime or graphite washes. The object of the coating is not to prevent sticking, but rather to provide a somewhat roughened surface which will assist the escape of air and gases during pouring—that is, to yield an effect similar to that of a rough machined surface, as described above. Coatings or washes are not favoured in American practice. It may be pointed out that when a mould begins to fail by the development of local surface checking or roughness, the flawed spots may be touched up with a lime wash between pours, thereby prolonging the life. However, the attempt to apply coatings in tonnage pouring reduces the speed of operation, increases costs, and makes necessary the use of a larger number of moulds.

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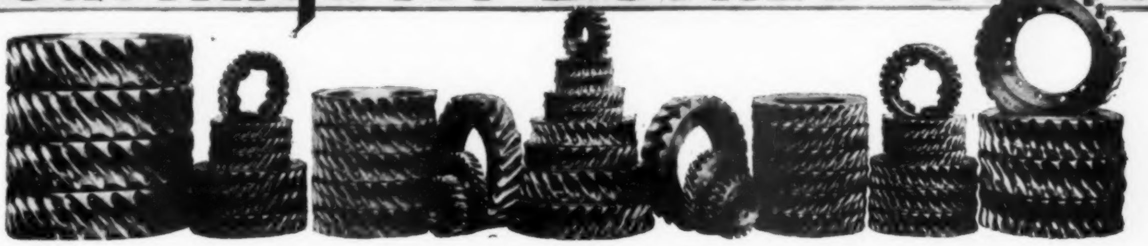
* Reference should also be made to the papers cited in the previous article of the series.

In the next article of this series the operation of ingot moulds and the pouring of rolling ingots will be discussed.

Castings for Bronze Gears



Part III.

By Francis W. Rowe, B.Sc., M.I.M.M.

Density, as well as hardness, is a desirable property of gear bronzes, and the author discusses the relative advantages of production processes to obtain increased density.

PLAIN sand castings cannot, by reason of their inevitable low density, lack of homogeneity in varied sections, and the inherent risk of variation in physical properties, successfully meet the high stresses prevalent in modern automobile back axle drives. The lower density in a sand casting is due to the slow rate of solidification which occurs in sand moulds, and, in some instances, lack of provision for compensation of liquid shrinkage.

The hardness, density, and other physical properties of any non-ferrous alloy are profoundly influenced by the rate of solidification. The rate of solidification is influenced by the nature and initial temperature of the mould material, the temperature of the metal poured into it, and, of course, by the mass. Given equal conditions, the lower the initial temperature of the mould and the higher the thermal conductivity of the material from which it is made, the greater will be the hardness and density of the metal. Similarly, the nearer the temperature at which the metal is poured to the solidus the higher will be the hardness and density. In practice, however, this latter statement needs some modification with very low casting temperatures.

Typical curves illustrating the effect of casting temperature on density and hardness are shown in Figs. 8 and 9.

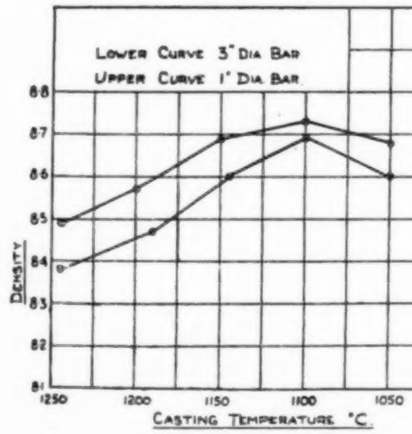


Fig. 8.—Illustrating the effect of mass and casting temperature on the density of 90/10 Tin Bronze. Drys and moulds bars cast vertically.

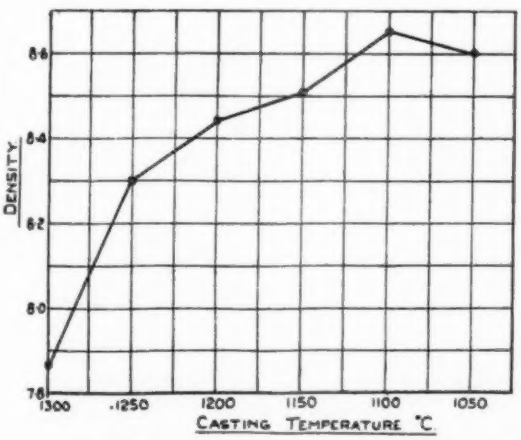


Fig. 9.—Effect of casting temperature on density of 89/11 Tin Bronze Bars, 1 in. dia., cast dry sand. (Horizontal.)

The determination of the density of a bronze for worm gear forms a most useful guide as to its suitability for this duty, and is one of the physical properties which should be most frequently checked. Fortunately, the effect of any variations in composition on the density is very slight. The theoretical mean densities (calculated from the percentage of each element) of the alloys normally used for gears—*i.e.*, those containing from 10—13% tin, and from 0·1 to 1·0% phosphorus, vary from 8·73 to 8·77. These are calculated from the highest recorded densities for copper (8·94), and tin (7·30). Actually, however, in practice it is found that densities appreciably higher than these are possible. The highest density figure in the author's records is 8·88. The range of densities obtained in practice vary from 7·90 to 8·85—the lower figure being frequently obtained in poorly made sand castings of fairly large mass.

That such low densities are solely due to loose packing of the crystals is shown by compressing specimens of such bronze. When loads up to 120 tons per square inch are applied the density can be very materially raised. On the other hand, specimens possessing high density to commence with show very little difference after having been compressed. For instance, a sand-casting specimen having an initial density of 8·23 had its density increased to 8·62 after being subjected to a compressive load of 60 tons per sq. in.

Further typical figures in this direction are shown in Table II., which indicate that the highest maximum density can be very nearly reached in the centrifugal method of casting.

Another inherent liability of sand castings is that of varying physical properties in varying sections. This is well illustrated by the casting shown in Fig. 10. This was cast in dry sand from 1,130° C., and was fed with a riser 1¾ in. diameter on the thick portion, being run from the thin end. The density of the thin portion (due to the thinness and rapid cooling) represents nearly the highest that can be obtained, but the density rapidly decreases with the increase in section. The density of 8·27 in the section 3 in. × 3 in. (by no means a large section when considering gear blanks) is typical. The general macrostructure of this casting is shown in Fig. 11, and it will be seen that the macrostructure does not, in this instance, give any indication of the differing

density, although the grain size shows clearly the method by which the casting was run, and the mould filled.

Since high hardness and density are desirable properties in a tin-bronze for gearing, it is only logical that the speeding up of solidification should be obtained by employing chills in the moulds, and very few gear blanks of from 10 lb. to 100 lb. in weight are cast, or ought to be cast, in plain sand moulds to-day. A peripheral cast-iron chill of sufficient mass (usually 1½ in. to 2½ in. thick) to ensure a good depth of chill is incorporated into the mould to ensure that that portion of the casting which will ultimately constitute the teeth is quickly solidified, and thus has a high density and hardness.

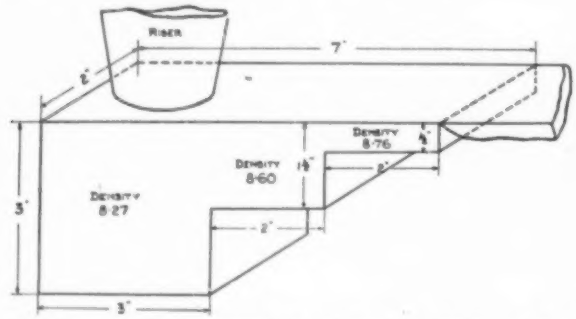


Fig. 10.—Test Casting poured in dry sand to illustrate effect of varying section on density of a Casting.

Unfortunately, chilling the tooth portion in this manner brings in its train disadvantages, some of which are difficult to overcome. First of all, there is the question of compensation for the heavier liquid shrinkage which naturally takes place. If a chilled casting is run with similar runners and risers to those normally used for the same castings in sand it will be found that the density and soundness of the chilled portion has been obtained at the expense of that part unchilled. For instance, a gear rim, 2 in. face × 2¼ in. thick, cast with a peripheral chill, and similar runners to those used for sand casting had a density in the chilled portion of 8·78, whereas the density in the unchilled portion was 8·23.

It is, therefore, necessary to use much heavier risers to secure adequate feeding. If the gear blank has internal bosses, as many designs have, these also are likely to be porous if left unchilled. To secure anything approaching a really sound and dense casting by chilling, very careful attention is needed to the size and disposition of the chills, and heavy risers are essential, and the size and position of the runners need careful planning.

Fig. 11.—Macrostructure of Casting shown in Fig. 10.

Each type and size of casting needs different treatment, and with new designs careful experimenting is necessary. This renders casting with chills a somewhat uncertain method, particularly if the quantity required of any one type is not large enough to warrant expensive trials to ascertain which methods give the best results. As examples of chilled castings, photographs are shown in Figs. 12 to 15 of two typical examples. Figs. 12 and 13 are of wheel 12 in. diameter, and weighing 48 lb.—a typical worm-wheel blank for a heavy vehicle back-axle drive. Those portions which have been chilled are painted white, and the runners (marked R) outlined in white, as also are the risers.

It will be seen in Fig. 12 (which is taken showing the underside of the casting) that the peripheral chill embraces also a portion of the side face. Chills have been used underneath all the bosses. The casting has been run at the bottom of four bosses, and those bosses not used for runners have been chilled on the inside also. Fig. 13 shows the top side of the casting which is unchilled, and shows the four massive risers covering the width of the top face and a portion of the register. Figs. 14 and 15 are of a wheel 13½ in. outside diameter, and weighing 73 lb., of a rather different type. Again, the peripheral chill embraces the whole face width and a portion of the bottom face. The underside of each boss is chilled, and each boss to which a runner is not attached is chilled on the inside also. Four runners attached to bosses on the bottom inside are used, and Fig. 15 (showing the top side) indicates the four heavy risers.

To founders not familiar with gear work, this method of moulding may seem excessively elaborate and expensive, but anyone who has studied the subject and the properties of castings made by various methods will appreciate that it is only by such procedure that anything like a reasonably sound and dense casting can be secured when using the chill-sand method.

TABLE II.

Effect of Compression on Density of Bronze.

Description.	Original Density.	After Compression 60 tons per Sq. In.	After Compression to 120 tons per Sq. In.
Sand casting	8·07	8·58	8·68
,, ,,	8·06	8·57	—
,, ,,	8·26	8·64	8·72
,, ,,	8·23	8·62	—
,, ,,	8·42	8·70	—
Test bar, 1¼ in. dia.	8·43	8·69	—
Chill casting	8·53	8·73	—
,, ,,	8·66	8·75	—
Centrifugal casting	8·80	8·83	8·84
,, ,,	8·83	8·83	—
,, ,,	8·85	8·86	8·88

Founders and users of gear blanks should remember always that the visual appearance of a blank, whether in the fully machined condition or not, cannot convey much useful knowledge of the soundness, density, or strength of the material. To accept and be satisfied with castings merely because the appearance is satisfactory and no glaring faults or unmistakable porosity show, is to be lulled into a false sense of security. Apart from the difficulties and precautions necessary to secure a reasonably dense and sound chilled casting, there are other attendant disadvantages of the chill sand casting which make it fall short of the ideal to be aimed for.

Primarily, there is the question of strength. The author has cut up very many chill sand castings made both at the foundries with which he is connected and by all other prominent foundries producing this type of casting. He has also had the privilege of having the results obtained by the leading users of gear blanks. Examination of the results of test-pieces cut from the chilled and working portions of the blanks show the highest tensile strength recorded for this type of casting in the compositions usually employed—11—12% tin and 0·10—0·5% phosphorus—to be 16·6 tons per square inch, associated with a Brinell hardness, at 1,000 kilogs., of 82.

The average tensile strength is usually about 14·5 tons per square inch, in normal sections—that is, from a sectional

area of 4 to 10 sq. in.—and frequently as low as 12 to 13 tons per square inch. This somewhat low tensile strength is in part due to the tendency for radial orientation of the chill crystals, similar to those shown in a typical wheel cross-section in Fig. 16.

Whilst this tensile strength is usually not appreciably lower than is met with in similar sand castings (and, of

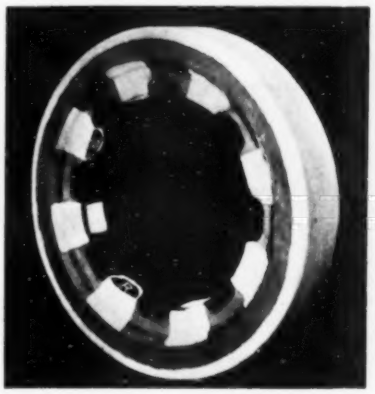


Fig. 12.—Typical Wormwheel Blank made by the Chill-sand method. Chilled portions painted white, and runners on bosses painted round.

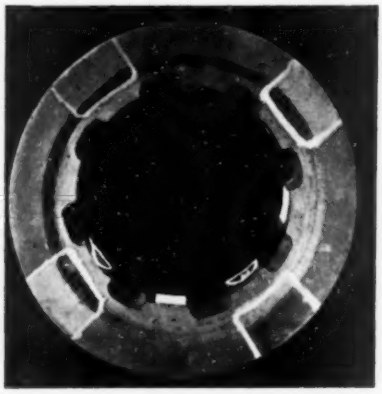


Fig. 13.—Top side of Casting shown in Fig. 12, showing large Risers extending into the register necessary to give adequate feeding on a dulled Casting.

course, is associated with a greater hardness than sand castings), it is not the highest that is possible with this type of alloy, as will be shown later with centrifugal castings.

A further disadvantageous feature of the chill-sand method of casting is that the type of microstructure obtained in the chilled periphery (and, therefore, in the toothed portion of the wheel) is not the best of which the alloy is capable for resisting wear and giving the lowest coefficient of friction.

When a mould consists of chills set in sand, the primary rate of solidification in the chilled portion is high, resulting in high density and hardness. The rate of cooling after this, however, is such as to result in the alpha solid solution being richer in tin (and consequently a lesser amount of $\alpha\,\delta$ eutectoid present) than is the case in either a sand casting or a fully chilled casting, such as a chill-cast stick.

Normally, copper is capable of retaining tin in solution up to 15%—that is, a copper tin bronze with 15% tin in perfect equilibrium consists solely of crystals of alpha solid solution. In actual practice a cast bronze, due to its rate of cooling, after solidification, has only about 7% of tin in solid solution, the rest forming the delta compound, with approximately 30% of tin and the hard $\alpha\,\delta$ eutectoid. If the casting is subsequently annealed or heat-treated, all or some of this $\alpha\,\delta$ constituent is absorbed.

The aim throughout in casting bronze for gears is to keep the alpha solid solution as low in tin as possible, to secure the essential difference in hardness between the two constituents, and secure the desired amount of $\alpha\,\delta$ present.

Figs. 17 and 18 show the comparison between the chilled and unchilled portions of a gear blank and the partial absorption of the $\alpha\,\delta$ in the chilled portion.

Whilst on this subject of influencing the relative proportion of α to $\alpha\,\delta$, it should also be mentioned that this is influenced also by casting temperature, the bronze cast at a higher temperature having less $\alpha\,\delta$ than that cast at a lower. It should be clearly stated, however, that the advantages of the chill-sand casting, if properly made, over the sand casting outweigh the disadvantages.

Centrifugal Casting.

The organisation with which the author is connected used the chill-sand method of producing castings for a large number of years, and, in fact, still do for certain types and designs of castings. Appreciative, however, of the limitations of this method, they set to work many years ago to see if by casting centrifugally the disadvantages of the chill-sand method could be eliminated. The early attempts proved sufficiently promising, and the process was persevered with, despite many initial difficulties. The first centrifugally cast worm-wheels to be put into service commercially in this country were put out by David Brown's in 1923, and since that date the process has progressed steadily. In 1926 the whole of this firm's production of automobile worm-wheels was turned over exclusively to this method.

The primary attraction of the centrifugal method of casting is the automatic feeding under pressure, due to centrifugal force; dispensing with heavy risers and giving a higher pressure than can be secured by any commercial height of riser.

As the metal in the steel centrifugal mould contracts, metal is forced in by the centrifugal action at a pressure varying from 55 lb. to 95 lb. per square inch, dependent on the internal diameter and speed of rotation. That such combination of casting under conditions of extremely rapid solidification, coupled with this type of feeding, gives the highest possible density even in large sections, is shown by the fact that by this method it is possible to secure castings the whole cross-section of which show densities of 8·84 to 8·86, and that it is impossible to increase this density appreciably, even under loads of 120 tons per square inch. Reference is here made again to Table II.

Apart from this high density, regular throughout the cross-section, the centrifugal casting possessed other advantages. In particular, the grain size is smaller than

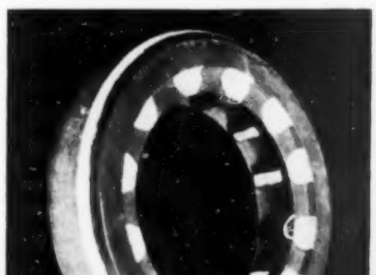


Fig. 14.—Chill-sand-cast Wormwheel Blank. Chilled portions marked white, and Runners painted round.

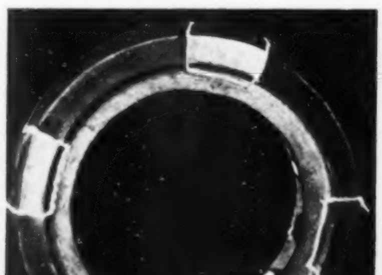


Fig. 15.—Top side of Wormwheel Casting shown in Fig. 14, showing the four large Risers essential to compensate for liquid shrinkage.

with any other type of casting. At first sight, one is apt to attribute the small grain size of the centrifugal casting to the fact that it is heavily chilled, but this is definitely not so. Whilst casting in chills does reduce the grain size, the infinitely small grain size which can be obtained with a centrifugal casting is due to the constant agitation during

the whole period of solidification, thus preventing the growth of long dendrites.

This heterogenous orientation ot small crystals undoubtedly contributes to higher strength, and, whereas the average strength of the good chill-sand casting is round about 15 tons per square inch, that of the centrifugal casting is about 19 tons per square inch for material of similar composition.

The author has frequently had figures of 21—23 tons per square inch, and it is very seldom even with the tin and phosphorus on the high side that the tensile strength drops below 17 tons per square inch. The disposition and quantity of the $\alpha\ \delta$ eutectoid is very satisfactory, as will be seen from the micrographs in Figs. 19 and 20, comparing a typical sand and centrifugal casting. The $\alpha\ \delta$ is finely dispersed and present in maximum quantity.

Fig. 16.—Typical macro-structure (showing radial orientation of crystals in chilled portion) of chilled blank: Mag. 2 dias.

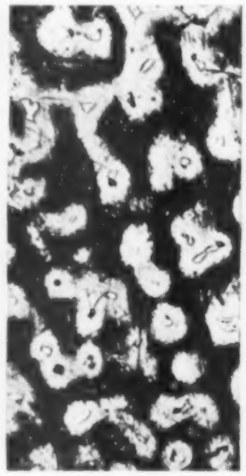


Fig. 17.—Typical micro-structure of chilled portion of chilled blank: Magnification 200 diameters.

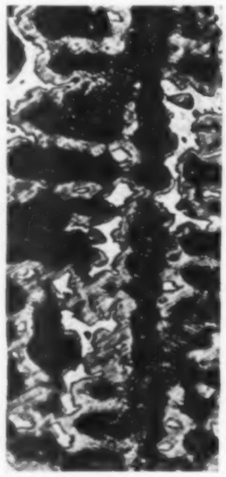


Fig. 18.—Typical micro-structure of unchilled portion of chilled blank: Magnification 200 dias.

Fig. 19.—Typical micro-structure of sand-cast bronze blank: Magnification 200 diameters.

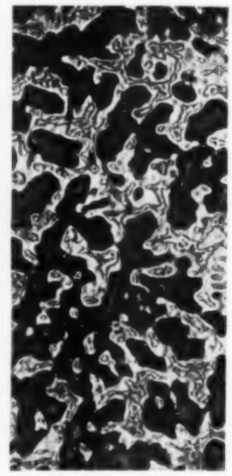


Fig. 20.—Typical micro-structure of centrifugally cast bronze blank: Magnification 200 diameters.

Probably one of the most attractive features of the centrifugal method of casting is the uniformity of results (provided, of course, the essentials of the process are realised) that can be obtained in varying sections, and the conditions can also be standardised to give a less degree of variability, between castings of the same type made at varying times, than with other methods of casting.

In practice, the mould for centrifugal casting is built of steel, suitably jointed and clamped to secure easy ejection of the casting. The mould is revolved about a vertical axis, and set at a height to allow of easy pouring. The mould is driven by a variable-speed direct-current motor, and the driving mechanism also includes change-speed gears, so that the speed of the mould can be varied within the range 200 to 1,500 r.p.m., which covers the practicable and necessary range for various types and designs of castings.

Since the majority of castings made have other than a plain interior, cores have to be used in the majority of designs. These are made of sea sand, with a suitable binder. It is necessary for the cores to be much stronger than is the case for ordinary work, since the heavy wash of metal and the centrifugal force have to be withstood. The cores have a central orifice for pouring, and, of course, no risers need to be provided for, as is the case with other methods of casting, including die-casting.

It is impossible to give any definite rules for casting temperature, as this is entirely governed by the shape and mass of the gear blank being handled, the distance the metal has to travel and the size of the runners necessary. Actually, pouring temperatures between 1,090° C. and 1,270° C. are used to obtain a similar high density product with various types of casting.

The whole secret of successful centrifugal casting lies in standardisation of casting conditions for different types, and particularly in constant testing and experiment when new designs are undertaken. It is definitely not a process to be undertaken by foundries not having the services of a well-equipped laboratory at their disposal nor by a firm who hopes to cut its costs below those of its rivals by eliminating, perhaps costly, but entirely necessary, methods of control. A poor centrifugal casting can be a very weak and unsatisfactory article, as slag inclusions and laminations inevitably lead to service failures. On the other hand, conducted by skilled technicians with a scientific understanding of the process, it undoubtedly gives a material superior to any other method of casting.

(In the next article the author will deal with the effect of compositions varying on the properties of the various types including of castings as regards physical characteristics, resistance to wear, pitting, and coefficient of friction).

Co-ordination of Iron and Steel Specifications.

The Iron and Steel Industry Committee which was appointed by the Council of the British Engineering Standards Association at the end of last year, to consider the question of the co-ordination of the iron and steel specifications, has now commenced work. At a recent meeting the manufacturers' representatives stated that during the past year the industry had been asked to work to no fewer than 250 separate specifications, many of them varying from one another in only minor and unimportant details. That this multiplicity of specifications adds enormously to the cost of production cannot be too strongly emphasised.

A small Committee representative of the various branches of the iron and steel industry has now been set up to review existing specifications, both British Standard and others, in the hope of being able to put forward recommendations for simplifying and so improving this most unsatisfactory position. The Committee will naturally keep in mind the fact that particular circumstances may quite distinctly warrant the framing of particular requirements. On the other hand, there can be no justification for the present chaotic conditions, and the sooner some measure of co-ordination is effected the better it will be for both the using as well as the producing interests.

It is hoped that the users generally recognising the economic value of this endeavour will support the efforts of the Committee, which will be directed to covering the present legitimate requirements of users by the minimum number of specifications.

Hardening Metals by Rotating Magnetic Fields

By E. G. Herbert, B.Sc., M.I.Mech. E.

The author describes his discovery of remarkable changes produced in metals by the action of a rotating magnetic field.

THE increase in hardness which occurs in previously work-hardened metals when they are subjected to low temperature annealing has been the subject of much research. It has also been shown that work-hardened metals are likely to increase in hardness as a result of ageing. The use of the "Cloudburst" process† for producing a work-hardened surface on metals by bombardment with hard steel balls has also been shown, and led the author to investigate these phenomena with a view to their practical application in increasing the hardness of the work-hardened layer, and also to stimulate research in an endeavour to discover something of the physical basis of the phenomena of the relationship to the previously known low-temperature changes in metals—viz., those changes in their ductility and work-hardening capacity which are found to occur at temperatures below 400° C. In this investigation* experiments showed that the hardness of various metals was increased by rotating them in a magnetic field. The results seemed to indicate a step forward in our knowledge of the interatomic world, as by means of a magnetic treatment a degree of super-hardening was achieved equal to that produced by an anneal at a low temperature. The author has further described his discovery of remarkable changes in metals by the action of a rotating magnetic field ; in a communication published in the "Proceedings of the Royal Society," A, Vol. 130, 1931, as follows :—

It has been observed that metals in a work-hardened condition, and in particular hard steel which had been super-hardened by the "Cloudburst" process of bombardment with steel balls, exhibit a propensity to become still harder by a process of ageing, the spontaneous increase of hardness commencing with the termination of the work-hardening process, and continuing during a period of several hours or days.

It was assumed that this spontaneous hardening connoted some atomic rearrangement of an unknown character, and it seemed possible that this arrangement might be assisted, in a magnetic metal, by applying an artificial atomic disturbance, such as might be caused by a magnetic polarity of changing direction.

Experiments proved this supposition to be correct. The work-hardened steel was placed across the poles of an electro-magnet, and slowly rotated fifty times in one direction and then fifty times in the reverse direction. The result of this magnetic treatment was found to be a distinct increase of hardness.

The electro-magnet used in these original experiments, and in those to be described, was one which had formed part of an Einthoven string galvanometer. The weight of the magnet is 30 lb. The gap between the cast-iron pole pieces is $\frac{1}{8}$ in. wide. The magnetic flux in a steel specimen placed in contact with the poles and bridging the gap between them is 16,700 gauss. The strength of the open field in the same situation is 1,440 gauss.

The increase of hardness produced by this magnetic treatment having been associated, subjectively, with the spontaneous hardening which had taken place in the work-hardened metal, the question now arose whether there were cases among metals, apart from those which had been work-hardened, where a propensity towards increased hardness or spontaneous hardening by ageing occurred and whether in these cases also the propensity towards increased hardness could be assisted and intensified by the application of a rotating magnetic field.

It was known that in freshly quenched tool steel certain changes take place, accompanied by the evolution of heat over a considerable period of time, and experiments showed that there was also a spontaneous increase of hardness during several hours after quenching. This fact having been established, specimens of tool steel which had been quenched and suitably aged were subjected to the action of the rotating magnetic field, with the result that the hardness was decreased, but almost immediately thereafter an increase of hardness commenced and continued during a period of 3 to 4 hours.

The whole of the effects referred to above are seen in Fig. 1, which shows the variations of hardness with time after quenching, magnetic treatment, superhardening, and repeated magnetic treatment in a high-speed steel containing 0·7% carbon, 4% chromium, 1·0% vanadium

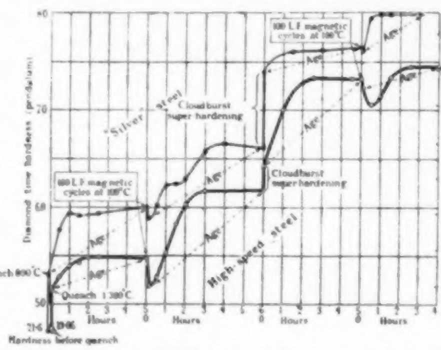


Fig. 1.—Silver Steel and High-speed Steel, quenched, aged, low-frequency magnetic treatment, superhardened by "Cloudburst," aged, frequency treatment (second time), and aged.

18% tungsten, 0·2% manganese, and in a specimen of "silver steel," believed to contain 0·8% carbon and a small percentage of tungsten.

The hardness measurements in the whole of these researches were made originally with the Herbert pendulum hardness tester. This instrument consists of a very short compound pendulum of 4 kilogs. weight, capable of being balanced on a spherical diamond of 1 mm. diameter. The natural period of oscillation of the pendulum is a measure of the hardness of any material on which it rests, the diamond sphere being the pivot. The "time hardness number" is the number of seconds (taken with a stop-watch) occupied by 10 single swings of the pendulum. This number is known to be related in a simple manner to other hardness scales, such as the Brinell, and for the convenience of those not familiar with the time-hardness scale, it has been converted into approximately equivalent Brinell numbers, the conversion factor in the case of hard steel being 13·5. In the cases of the softer metals, duralumin and brass, referred to later, the original researches conducted with the pendulum were repeated with the Brinell test (5 mm. ball, 125 kilogs. load, 30 secs. application). The Brinell test gave results entirely similar to those previously obtained with the pendulum, and the actual Brinell readings are given in Figs. 5, 6, and 7.

Referring to Fig. 1. the specimen of high-speed steel was quenched in oil from 1,300° C. Hardness measure-

† Iron and Steel Institute. Vol. 118, No. 11 (1927).
* Iron and Steel Institute. Vol. 120, No. 2 (1929).

ments were made immediately after quenching, and thereafter at half-hourly intervals, and stability was attained after the lapse of 2 hours. Magnetic treatment was then applied, consisting of 10° slow revolutions in the magnetic field at 100° C. Previous experiment had shown that the magnetic treatment of hard steel is more effective at 100° C. than at room temperature. In treating hard steels a light aluminium vessel was fixed across the magnet poles, and this was filled with water kept at boiling point by a gas burner, the specimen being rotated in the magnetic field of 14,500 gauss at the bottom of the water-bath.

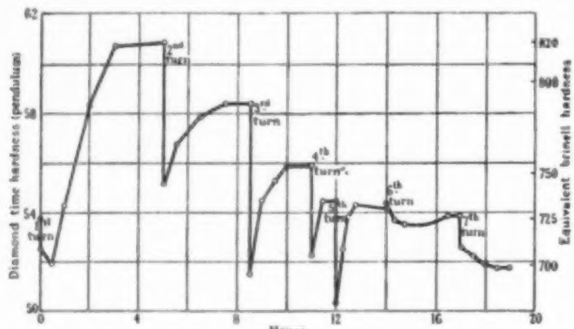


Fig. 2.—High-speed Steel. Effect of repeated magnetic treatment and ageing.

The result of the magnetic treatment was an immediate decrease of hardness followed by an increase, stability being attained after 3 hours.

The specimen was then treated by the " Cloudburst " process of bombardment with 3 mm. hard steel balls, falling at the rate of 500,000 per minute from heights which were increased by stages from 2 metres to 4 metres. The result of the " Cloudburst " superhardening treatment was an immediate increase of hardness and a much more considerable spontaneous hardening during the $2\frac{1}{2}$ hours following the treatment. (It was this age-hardening after " Cloudburst " treatment which first suggested the magnetic hardening process).

The specimen was then subjected to a second magnetic treatment exactly as before, which again resulted in a decrease and a subsequent increase of hardness.

A precisely similar sequence of hardening operations was applied to the silver-steel specimen (Fig. 1), and resulted in similar changes of hardness. The total increase of hardness from the moment of quenching was in the high-speed steel from 700 to 1,000 Brinell, and in the silver steel from 715 to 1,080 Brinell.

The effect of repeated magnetic treatment of the same specimen has been the subject of much investigation. The changes of hardness are of a highly complicated

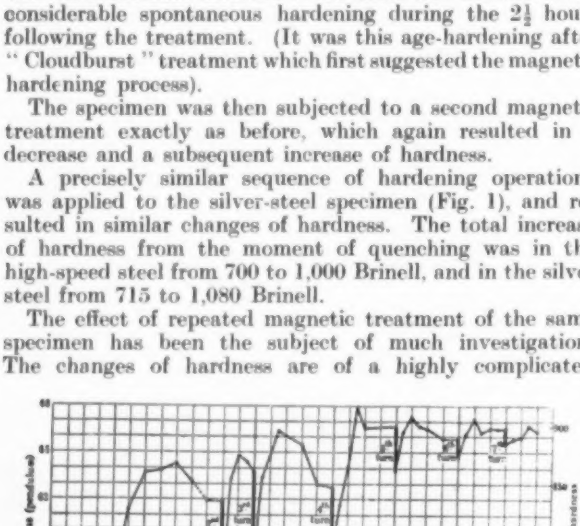


Fig. 3.—Steel (C. 0.70, Mn. 0.59, Si. 0.15); quenched 780° C., one turn in magnetic field at 100° C., repeated seven times.

character, as shown in Fig. 2. The specimen used in these experiments was of high-speed steel containing 18% tungsten. It was cut from a saw blade which had been hardened many months previously by the usual primary and secondary heat-treatments at 1,300° and 575° C. respectively, and it was assumed to have become stable. The magnetic treatment consisted of a single slow turn in the magnetic field at 100° C., experiment having shown that the effect of a single turn was almost identical in character and degree with that produced by a greater number of turns. The first turn produced an immediate fall of hardness, followed by a slight further fall during half-an-hour and a very pronounced rise during 3 hours. The second turn caused a great fall in hardness followed by a rise to a second and lower maximum, and this sequence of changes was repeated, but with diminishing amplitude, until after the seventh treatment there was only a slight decrease of hardness and no subsequent increase.

Fig. 3 shows a similar series of changes resulting from seven successive applications with ageing intervening. The specimen was of steel containing 0·76 carbon, 0·59 manganese, 0·15 silicon, and it was quenched and aged as shown prior to the magnetic treatment. The amplitude of the hardness variations here decreases as before, but a new feature appears in the decrease of hardness following the attainment of each maximum, and the general change of hardness is an increasing one.

Fig. 4 shows the result of similar treatment applied to a safety razor blade. The results are generally similar, but in the fifth and subsequent cycles there is a curious reversal of the sequence of hardness variations, the previous fall-rise-fall being changed to rise-fall-rise. Significance is attached to this phenomenon because it has been found to recur in other specimens.

Application to Non-ferrous Metals.

The process of age-hardening is not confined to ferromagnetic metals, indeed the most notable instance of this process occurs in the non-magnetic alloy duralumin. Extensive investigations have been made in the application of magnetic treatments to this metal, and as it was at first thought improbable that any effect could be produced in a non-magnetic metal by slowly rotating it in a magnetic field the first experiments were made (on duralumin

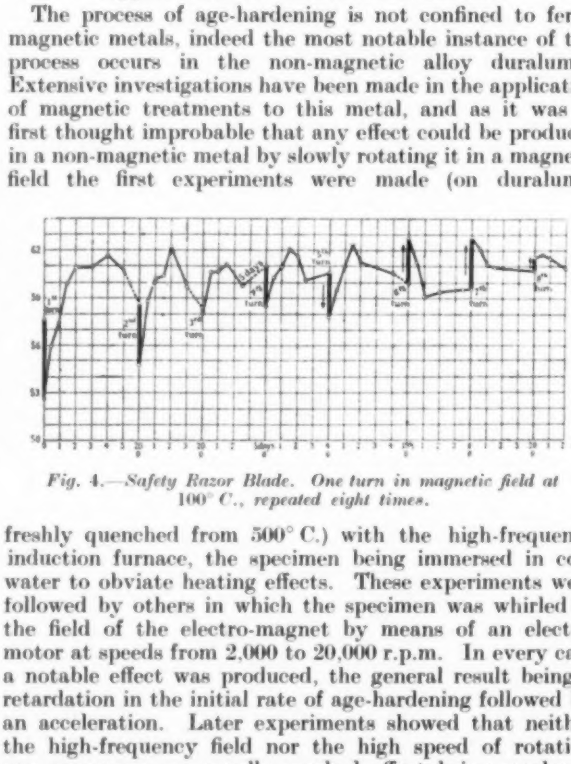


Fig. 4.—Safety Razor Blade. One turn in magnetic field at 100° C., repeated eight times.

freshly quenched from 500° C.) with the high-frequency induction furnace, the specimen being immersed in cold water to obviate heating effects. These experiments were followed by others in which the specimen was whirled in the field of the electro-magnet by means of an electric motor at speeds from 2,000 to 20,000 r.p.m. In every case a notable effect was produced, the general result being a retardation in the initial rate of age-hardening followed by an acceleration. Later experiments showed that neither the high-frequency field nor the high speed of rotation was necessary, an equally marked effect being produced by slowly rotating the specimen, at room temperature, across the poles of the magnet, or, alternatively, by inserting the specimen for a few seconds between the poles of the magnet, removing it, and reinserting it in a reversed position, the operation being repeated 20 times.

The effect of the last-named procedure is shown in Fig. 5. The experiment was first tried on a specimen of duralumin which had been quenched and aged, with the result shown at A. The sequence of hardness changes was a fall-rise-fall, as in the case of the hard carbon steels. When this treatment was applied to a freshly quenched specimen the result, compared with the normal age-hardening shown in the dotted curve, was a retardation, a great acceleration (the hardness attained in 12 hours being about equal to that normally attained in 34 hours), and finally a slight

fall. The same magnetic treatment applied to this specimen for the second time reproduced the sequence of changes shown at A.

These results suggest that the magnetic effects have been merely superimposed on the normal age-hardening process, and may be entirely different in character. A softening added to a hardening might be expected to result in a retardation, while a hardening added to a hardening would result in an accelerated hardening.

A further example of magnetic treatment applied to freshly quenched duralumin is seen in Fig. 6. In this case there was an actual softening, extending over the first 4 hours and followed by accelerated hardening. The treatment, 10 slow turns at room temperature, was applied six times, and in the fourth, fifth, and sixth cycles a reversal in the sequence of hardness changes, similar to that which occurred in the razor blade, is seen to have taken place.

Fig. 7 shows the result of applying two different kinds of magnetic treatment to brass. The lower curve refers to cold-rolled sheet brass, which was whirled for 5 mins. at 2,000 r.p.m. in the magnetic field. The resulting sequence of hardness changes is the same as that found in hard steel and in duralumin, fall-rise-fall, but the cycle of changes was slower, requiring 10¼ hours for its completion. In the upper curve, Fig. 7, are shown the results of slowly rotating a specimen of brass (a disc cut from a bar of commercial rod brass and quenched at 600° C.) across the magnet poles at room temperature. The sequence of changes and their duration are similar to those in the whirled sheet brass, and a reversal in the sequence of changes occurs after the second application, corresponding to the reversals in hard steel (Fig. 4) and in duralumin (Fig. 6).

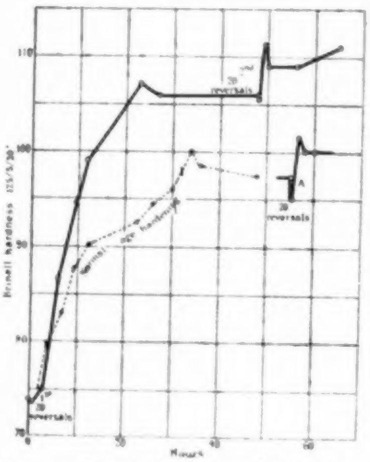


Fig. 5.—Duralumin. Quenched 500° C., reversed 20 times between magnetic poles.

The hardness changes here described are believed to indicate a rearrangement of atoms in the space lattice, or a change in the atoms themselves, but no explanation can be given and none will be attempted at the present stage. Some general observations may, however, be of interest.

The time element enters as an important factor into all the results produced by the rotating field, and it was the discovery of this fact, after a long period of rather fruitless research, which alone rendered possible the presentation of these results. The hardness changes are sometimes very rapid, and in hard steel freshly treated they may be observed from minute to minute.

The hardness induced by magnetic treatment is known to persist for months, and there is no reason to believe that it is other than permanent, though no systematic investigation has yet been carried over long periods of time.

Magnetic treatment has hitherto been applied to various high-speed steels and high-carbon steels in the hard state, to soft mild steel and soft high-carbon steel, to duralumin, and to brass. In every case a series of hardness changes has resulted, the sequence of changes being similar in character. As no metal hitherto subjected to magnetic treatment has failed to react, the possibility must be contemplated that these phenomena are common to all metals. They may not be confined to metallic or even to inorganic substances.

The temperature at which the magnetic treatment is applied has a marked effect on the resulting hardness changes. In the case of hard steel the treatment is less effective at room temperature than at 100° C., but the latter temperature was arbitrarily chosen, and further experiments may show a higher or a lower temperature to be more effective.

In the case of soft steel, the magnetic treatment has proved the most effective when applied to the cold specimen.

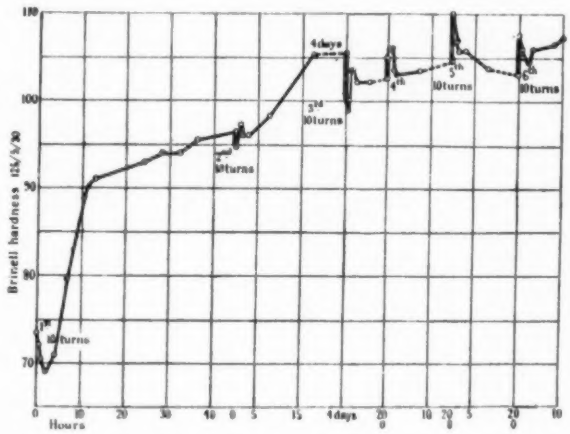


Fig. 6.—Duralumin. Quenched 500° C., 10 slow turns in magnetic field, repeated six times.

An increase of hardness such as would indicate an increase of 20% in the tensile strength has been induced in soft steel by a single rotation at room temperature, the maximum hardness being attained only after the lapse of 8 hours. The effect of temperature has not yet been investigated in the case of non-magnetic metals.

The practical applications of the magnetic treatment to hard tool steels are obvious. In Fig. 2 it will be observed that an equivalent increase of hardness from 725 to 820 Brinell was induced in high-speed steel by a single turn in the magnetic field, occupying about 1 min., and applied at a temperature of only 100° C. Such treatment could be given to finished tools of the simplest or the most complicated character, drills, saw blades, milling cutters, dies, or to other articles of steel in which a high degree of hardness is beneficial. The effect of the magnetic treatment on the hot hardness and on the actual cutting efficiency of tools is under investigation. The results obtained on unhardened steels as used in mechanical construction are encouraging, and will be further investigated.

In the non-magnetic metals the hardness changes hitherto produced have been relatively slight. The theoretical importance of these phenomena is believed to be great,

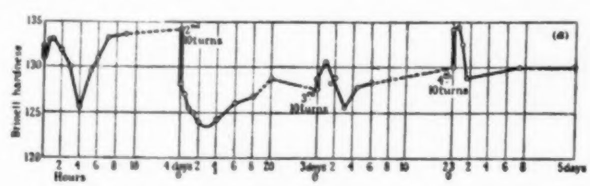


Fig. 7A.—Rod Brass. Ten slow turns in magnetic field, repeated four times.

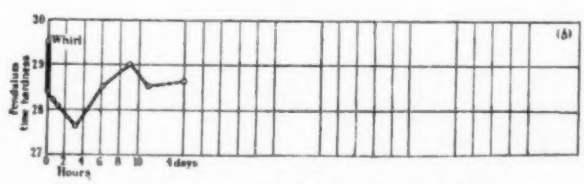


Fig. 7B.—Brass Sheet. Whirled five minutes at 200 r.p.m. in magnetic field.

but much further investigation will be required to ascertain the nature and extent and possible utility of the changes in the physical and mechanical properties of non-magnetic metals, of which the hardness changes are an indication.

Reviews of Current Literature.

Non-metallic Inclusions in Iron and Steel.

Slag inclusions have always been associated with iron and steel, and how to prevent their occurrence in the metal is a question of extreme importance. That the importance of the task is appreciated by all metallurgists is indicated by the extensive literature on the subject. The presence of non-metallic inclusions in metal reduces its quality, because slag denotes something inferior in relation to the metal. As a rule slag in fluid metal is readily separated because of its generally lower melting point and considerably lower specific gravity. But further investigations, particularly with the aid of the microscope, have shown that complete separation of the slag from the metal is not as easy as was at one time supposed, and, even with all the advantages of metallurgical developments, slag inclusions will be present in all commercial metals, although often in very small quantities. While much research work has been accomplished, owing to difficulties connected with the task and the comprehensiveness of the subject, the results obtained so far have not been entirely satisfactory.

The present work by Dr. Carl Benedicks and Mr. Helge Löfquist gives a detailed study of the published investigations on the subject, and this is used as a basis for further experimental work. The authors have given particular attention to detail, and have treated the subject more from a physical-chemical point of view than has previously been the case. The work is the direct result of the Scholarship presented to the Metallographic Institute in Stockholm by Sir Robert Hadfield in 1926. It was decided on the recommendation of Professor Arvid Johansson, the President of the Board of the Institute, to make slag inclusion in iron and steel the subject of the scholarship treatise. In planning this work, it was considered as most rational to make first a compilation of a critical examination ot the existing literature or the subject. The recipient of the scholarship, Mr. H. Löfquist, soon found that the magnitude of the undertaking would require more time than was allowed by the terms of the scholarship, but the Swedish Ironmasters' Association rendered assistance and appointed a committee to support the work. In this way the authors have been able to realise the plan of presenting a critical survey of the subject.

Some of the results and conclusions arrived at in the course of the research have already been published, but several observations are included in the present work, which is divided into seven parts. In addition to a brief outline of the purpose of the work, the introductory part considers slag inclusions from the point of view of the heterogeneous chemical equilibrium, defines the two main kinds of slag inclusions, and details the disposition of the subject matter with the method of giving literature references. In Part II. is given a general description of slags, including physical properties, which are of interest in the inclusion problem, and their equilibrium diagrams in relation to iron in so far as these are known, or can be derived from available data. Methods of qualitative and quantitative analysis of slag particles are considered in Part III., while Part IV. gives an exposition of the physical factors which influence the formation and distribution of slag particles in the metal bath and in the ingot. Various influences exerted on the material by slag particles are considered in Part V., while Part VI. deals with the amount of slag in different kinds of steel. The final part contains a short analysis of available metallurgical measures for lessening the slag content. A very comprehensive bibliography of the literature regarding slag inclusions is given at the end of the work.

This work will undoubtedly be recognised as a standard treatise. It provides the metallurgist, as well as the user of steel, with detailed information which serves to elucidate the genetic relation between slag inclusions and manufacturing methods; in addition, it will provide a basis and guide when planning further research into the slag problem, which is so important in the production of high-grade steel. It is a valuable work, and cannot profitably be omitted from the literature necessary to the manufacturer and user of steel.

By Dr. Carl Benedicks and Mr. Helge Löfquist. Published by Messrs. Chapman and Hall, 11, Henrietta Street, Covent Garden, London, W.C. 2. Price, 30s. net.

Proceedings of the Institute of British Foundrymen. Vol. xxiii., 1929-1930.

These proceedings contain the report of the Twenty-seventh Annual Conference held at Middlesbrough, June 17-20, 1930, together with papers and discussions presented at Branch meetings during the session 1929-1930. An indication of the progress of this Institute is shown by comparing the proceedings with those published a number of years ago. It is not only the considerable increase in membership that is noted, but a continuation of that enthusiasm displayed by the pioneers of the Institute, which accounts for the large amount of work covered during the session. Apart from the Middlesbrough Conference, at which nine papers were presented, together with the official report of the Test Bar Committee of the Institute, the energy displayed by the various branches has had much to do with the progressive spirit that permeates this organisation. Among many interesting and informative papers presented at Branch meetings and published in these proceedings are four papers which earned for their authors the Diploma of the Institute; these include "Electric Steel Founding," by Mr. D. K. Barclay, given before the Middlesbrough Branch; "Steel Castings," by Mr. C. H. Kain, given before the London Branch; "Steel Castings," by Mr. T. Service, given before the Scottish Branch; and "Some Aspects of Jobbing Moulding," by Mr. S. Southcott, given before the Wales and Monmouth Branch. Much excellent work is being done in the promotion and maintenance of Junior Sections and in visits to works. It is gratifying to note that a technical committee, which was formed with the object of initiating investigations, tests, and researches, is now functioning, and that close co-operation exists between this Institute and the British Cast Iron Research Association.

Institution of Mining and Metallurgy.

The Third (Triennial) Empire Mining and Metallurgical Congress was held in South Africa from March 24 to May 9, 1930, and a number of very useful and interesting papers on South African gold-mining were discussed. It will be of interest, especially to those who were not able to obtain the reports of these papers, to learn that a critical review of a number of them is contained in the *Bulletin* of the Institution of Mining and Metallurgy for April, 1931. This review, by C. B. Brodigan, is entitled "Rand Mining Practice," and refers to twelve papers dealing with almost every side of the subject. Other items in the *Bulletin* are discussions on "The Treatment of Hollinger Precipitate to Produce Fine Gold," "The Use of Hole-directors in Ground-breaking Control" by H. Simon, and further contributed remarks on "The Sampling and Estimation of Borehole Cores and Sludges, and on "Computation of the Probable Value of Ore Reserves from Assay Results."

Transactions of the Institution of Engineers and Shipbuilders in Scotland. Vol. lxxiv. Part v.

Two important papers are published in these transactions of the Institution of Engineers and Shipbuilders in Scotland: The paper on "The Stresses in Wire Drawing" by E. M. Horsburgh, M.A., D.Sc., and that on "Electric Welding in the Construction of Sea-going Vessels," by G. Wahl. Both papers created considerable interest and much discussion has resulted, which is included in this publication, as well as the discussion arising from the paper on "The Oil-pumping System of Two Modern Oil Tank Vessels," which was published in a previous issue of the transactions of this Institution.

Refractory Materials

Examination of Refractories in the Laboratory.

By Colin Presswood, B.A., F.G.S.

This author discusses various properties of refractory bricks, including density and porosity, conductivity of heat and electrical conductivity, and proceeds to consider spalling tests and the slag resistance of bricks.

Density and Porosity.

A KNOWLEDGE of its density is a useful guide to the probable service value of a brick. The same test may be applied to ramming compositions and cements before and after firing, and if the manufacturer's aim be to produce a composition which, after it has been heated "in place," has a high density, he will make tests of the density resulting from various bonds and gradings.

In the study of bricks it is important to remember that they have an "Apparent" and a "True" (or powder) density. Thus, a brick may be weighed and its volume measured. A simple division gives the apparent density, say, in terms of grammes per c.c. But the actual volume occupied by the brick material is less than that of the brick itself, because there are pores and cavities. If the density be determined by immersion in water therefore, a different figure will be obtained because the water has penetrated into the pores of the brick.

The density may also be determined by grinding the brick to a fine powder and placing this in water. The usual specific gravity bottle method has been improved upon by Rees and Hugill, who have designed simple apparatus which gives the powder density at once as a reading on a graduated neck. This method will give another figure in all probability, because in grinding the totally closed pores of the brick have been opened up. The water had no access to these in the other test. This is called the "Powder Density" test and yields the true specific gravity or density.

Clearly the powder density is higher than the apparent density, save in cases where the brick or shape has no pores whatsoever. The difference between the two figures is a guide to the volume of pores or, in other words, the porosity may be calculated therefrom. If S_a = apparent density, S_p = powder density, then

$$P \text{ (porosity) } \% = \frac{(S_p - S_a)}{S_p} \times 100.$$

Generally it is held that the higher the density the greater the slag resistance and resistance to corrosive gases and dust, etc. This seems reasonable, but there are outstanding anomalies which can well be illustrated by the success, in one power-station, of very porous, friable grog bricks. The anomalies are difficult to explain, and at present it is best to remember that the weight of evidence is in favour of low porosity.

The production of refractory bricks of low porosity is a difficult matter. Silica bricks will be found to range from 23 to 35% porosity. Very careful attention to grading, blending, moulding, and firing has produced bricks of about 17% porosity. Fireclay bricks show a still wider range, as certain qualities can be burnt to vitrefication in manufacture ("Buckley" type of blue firebricks. These are not highly refractory but serve a useful purpose in resisting abrasion at moderately high temperatures—*e.g.*, cement kiln pre-sintering zone). To vitrefy the purer and more refractory firebricks would be a difficult matter, especially as good shape is to be maintained consistently with reasonable cost.

As porosity and density are so intimately connected it is well to mention here another broad general principle—namely, that the denser a brick, the greater its tendency to spall when temperature changes suddenly. It is conceivable that the pores in a brick act as tiny expansion joints, allowing the individual grains to expand freely. On the other hand, it is reasonable to argue that pores may be the cause of spalling since they really weaken the structure, and closed pores, if gas filled, may certainly cause damage. I have certainly found magnesite bricks to show rather worse spalling at 35% porosity than at 25%. The difficulty of producing bricks free from all pores can be well illustrated by magnesite bricks, which, in spite of tremendous pressure, careful grading, high firing temperature (almost vitrefied) still show 22 to 25% porosity. The fact is that spalling is by no means thoroughly understood, nor has any test been evolved as yet which definitely yields results consistent with furnace practice.

If the two conventions be substantially correct, and density increases slag resistance whilst decreasing the power to resist spalling, we are faced with the need of compromise between mutually contradictory desiderata. Selection may be made according to the conditions in the furnace.

True, or powder, density serves in another way as an indication of quality. Certain of the refractory minerals undergo a permanent volume change when heated—*e.g.*, magnesite and silica. The extent to which these volume changes have been completed by the manufacturer can be indicated, as intimated previously, in the "after-expansion" tests. But the powder density also gives an indication of the extent to which, say, silica, has been thoroughly burnt. Quartz has a powder density of 2·65 and inverts into cristobalite and tridymite, whose powders have density of 2·27 and 2·33, respectively. A silica brick which has been underfired will contain a large percentage of unconverted quartz which, in use, will be inverted and expand. A powder density determination on such a brick will serve as a guide to the amount of quartz present. Similarly, the powder density, coupled with micro-examination, will help in estimation of the amount of tridymite present. (See later under silica bricks where examples will be given.)

Magnesite, when dead burnt, inverts to periclase, whose powder density is about 3·6, and the powder density has been used as a test of the thoroughness or otherwise of "dead-burning" or shrinking in supplies and in bricks. Density (and porosity) thus give a guide to the service value as far as concerns slag resistance and spalling, and, in some types of material, indicate the liability to permanent volume change.

Porosity, it should be mentioned, is indicative of thermal conductivity, although, as will be mentioned later under heat insulation, it is by no means an exact method of determination. If conditions in a furnace do not call for a dense brick, then a porous brick can be used with a view to fuel economy.

Conductivity of Heat.

The various pure minerals used as refractories each have a characteristic thermal conductivity of which the importance is being increasingly recognised. The intrinsic conductivity may be considerably modified by such features

as porosity, fluxes, etc., when the minerals are formed into bricks, and the variation shown by bricks of the same broad class—viz., fireclay bricks, is illustrated by figures quoted by Norton (Journal American Ceramic Society, January, 1927), who shows a range of 0·00135 to 0·0037 c.g.s. units. Conductivity, moreover, generally increases with temperature, the figures for the same brick being 0·0024 (at 200° C.) to 0·0042 (at 1,400° C.) (Norton, *loc. cit.*). Table I., however, shows a *decrease* for magnesite and silicon carbide bricks.

Typical figures are shown in Table I., which includes a variety of brick types, and from the variation of conductivity with temperature the desirability of always noting temperature at which a figure was determined will be apparent.

TABLE I

CONDUCTIVITY OF VARIOUS BRICKS AT VARIOUS TEMPERATURES.

Brick.	Thermal Conductivity C.g.s. Units.	Temperature at which test was made. ° C.	Authority.	Representative Figures.
*1. Diatomite insulating brick (burnt)	0·000260 0·000350	162/8 617/80	N.P.L. "	1 1½
2. Diatomite insulating brick (raw)	0·000260	750		1
3 Fireclay brick, Missouri	0·0024 0·0042	200 1400	Norton	9 16
4. "Firebrick"	0·00135 0·00206	800 1000	Green quoted by Norton	5 8
5. Silica brick	0·0028 0·0054	200 1400	Norton "	11 21
6. Chrome brick	0·0034 0·0041	200 1400	" "	13 16
7. Magnesite brick	0·0137 0·0085	200 1400	" "	52 33
8. Silicon carbide brick	0·0440 0·0260	600 1400	" "	170 100

* Norton, in *Journal of American Ceramics Society*, Jan., 1927.

Interest in thermal conductivity centres chiefly round fuel saving, and figures are particularly valuable for insulating bricks. (See later section.) Whether insulating layers are used or not, the firebricks exert considerable influence, and, there being no opposing consideration, the least conductive bricks should be used. When a refractory wall is backed up by diatomaceous insulating bricks its conductivity is a guide to its thickness, since the higher the figure the greater the thickness necessary to protect the diatomite from excessive temperature.

Conductivity has a distinct influence on spalling, which is dealt with below.

Electrical Conductivity.

The electrical properties of refractory materials are not widely known, nor are they, in general, nearly so important as the properties previously mentioned. Conductivity is to be considered, however, in electric furnaces, and in the manufacture of heating elements in which wires and rods are embedded in a refractory cement.

In general, refractories are good resistors at moderate temperatures, but nearly all show a big drop in resistance at 1,400° C. to 1.550° C. Thus, Diepschlag and Wulfestieg show that resistance of MgO in ohms per cu. cm. falls from 158,000 at 1,100° C. to 1,105 at 1,550° C. King shows that periclase has infinite resistance over the range 713° C. to 990° C. (Journal American Ceramic Society, June, 1926). He finds sillimanite resistance infinite at 713° C., but 124,000 at 990° C.

Chrome bricks have poor resistance, and a cement with chrome ore as base has certainly failed when used for embedding nichrome wires, though in this case there were, no doubt, chemical reasons for the failure. Pure silicon carbide, first-grade fireclay bricks, bauxite bricks, and lime-bonded silica bricks have shown regular resistance curves.

Diepschlag and Wulfestieg give the following results for pure minerals :—

TABLE II

Material Tested.	Experimental Temperatures. 1100° C.	1250° C.	1400° C.	1550° C.
	Ohms per cu. cm.			
MgO	158,000	16,395	2,500	1,105
SiO_2	161,000	41,320	12,050	5,950
Al_2O_3	133,100	58,000	12,000	4,080
CaO	117,740	34,180	10,180	830
Fe_2O_3*	434	423	—	—
Mn_3O_4*	710	603	—	—

* Specimens were reduced.

They dealt principally with commercial magnesite and found that :—

(a) The addition of MgO, SiO_2, and CaO reduces resistance at 1,100° C. and 1,250° C.; increases resistance at 1,400° C. and 1,550° C.

(b) The addition of Fe_2O_3, and Mn_3O_4 reduces resistance at all temperatures.

(c) Fine grain size and increased pressure reduce resistance.

(d) Unstable mineral systems show most irregular results, but better regularity can be obtained if specimens are held at high temperatures for a long time before being being tested. This points to the need for thorough heat-treatment in manufacture.

(e) Resistance curves for magnesite are very irregular as the commercial mineral is not homogeneous.

For magnesite bricks they gave the figure of approximately 76,000 ohms per cu. cm. at 1,100° C., which falls to less than 100 ohms per cu. cm. at 1,550° C.

Spalling Tests.

Spalling, or the cracking of a brick when its temperature changes, probably causes more damage than any other factor operating during use. The bricks may either crack into fairly large pieces which become detached, or the face only may become friable and small particles fall off as coarse dust. Primarily, the trouble is due to expansion and the inability of the brick to withstand the consequent stresses.

The consolidation of a refractory brick is effected by surrounding assorted sizes of relatively coarse, highly refractory grains with a thin film of material less refractory. This material—a mild flux—may be added deliberately—*e.g.*, lime in silica bricks, or may be incidental to manufacture. Thus, in grinding, infinitely small grains of the refractory surround the coarser grains and, because of their fineness, melt more easily than the coarse grains. The brick, therefore, comprises more or less coarse grains cemented together by material which has been semi-fused to form a "glass." This "glass" is often highly sensitive to temperature changes, and cannot withstand expansion stresses if these are applied suddenly. The object of the brick manufacturer is to produce no more "glassy matter" than is consistent with a hard brick. Bricks which are overburnt or vitrefied may spall badly when the same material reasonably, or under, burnt, will resist spalling.

Spalling is thus due to :—

1. The intrinsic expansion of the material, which may be variable even when the temperature rises uniformly.
2. The amount of "glass" present in the brick, and the extent to which it is "elastic" or able to withstand stress outwardly imposed, and the extent to which it is, itself, sensitive to temperature changes.
3. Uneven temperature in the brick.
4. The extent to which the brick is free to expand.

It is probable that by far the greatest damage by spalling is done at relatively low temperatures, say, below 1,100° C. Above this temperature the "glass" begins to soften in part at any rate, and the highly viscous material produced allows the expanding particles to adjust themselves. In silica bricks this is fully realised, as it is well known that cristobalite, the main constituent, expands rapidly at 270° C., but with other bricks which may have regular expansion the point is often overlooked. The expansion characteristics of the principal refractory materials will be illustrated later and will be shown to vary widely as to total amount and the rate at which it takes place.

The manufacturer may modify the spalling tendencies of any materials by careful grading and blending, and control of firing temperature and time (see remarks under Porosity and Density above). In addition, as expansion and contraction movement may be due to the continuance of chemical and physical changes when materials are in use (these changes being incomplete, as mentioned under "After-Expansion"), he can often reduce spalling by completing the changes as far as possible. Thus, fireclay bricks spall less in some cases if a high proportion of the clay be thoroughly shrunk before being finally ground and moulded—a point to be elaborated under "Chamotte" bricks in a later article. As a further instance silica bricks may spall less if they are so blended and heated as to convert all the quartz, preferably into Tridymite.

The user may overcome spalling troubles by :—

1. Slow heating, especially at temperatures where expansion is irregular.*
2. By the provision of "expansion joints" equal to the total reversible expansion of the wall. These may be at intervals—say, 1 in every 100 in. of wall, or around each brick in the form of a tar joint. Magnesite and silica bricks are often set in tar or pitch with advantage.
3. By ensuring that, as far as possible, all parts of the furnace wall are heated simultaneously, and such devices as tie-rods adjusted properly.

The investigation of spalling in the laboratory is by no means a success as yet, and there is no accurate index figure of "spallability." The matter has been widely considered—*e.g.*, by A. T. Green, in this country, and by Norton, in U.S.A.—and attempts at evolving a formula from which tendency to spall might be estimated are interesting.

Thus, Norton calculates spalling tendency as—

$$S \text{ varies as } \frac{D}{h\,p}$$

where D = Coefficient of expansion, h = "Diffusivity," p = Maximum shear strain, and finds the values roughly proportional to laboratory tests of spalling.

"Diffusivity," the significance of which has been emphasised by A. T. Green, is calculated as—

$$h = \frac{k}{c\,g},$$

where k = conductivity, g = density, c = specific heat.

It is clear that the rate of heat diffusion through a mass depends on each of these three factors, and that upon "diffusion" of heat throughout the thickness of a wall depends the temperature gradient which imposes a stress if there be expansion.

In the laboratory spalling tendency may be roughly measured by the number of heatings and coolings a brick will undergo before 20% of its weight is lost by spalling. In the most commonly accepted form this test comprises closing the "doorway" of a furnace (maintained constantly at 1,350° C.) with five or six bricks in such a way that only the ends of the bricks are exposed to the heat. No jointing is used, and the bricks are not fitted tightly into the doorway. They are exposed for one hour to the temperature, and then the hot ends are immersed in running cold water for a fixed time. The time of subsequent steaming is also fixed and the operation repeated.

This serves to distinguish between broad classes of bricks—*e.g.*, silica and sillimanite—but it is doubtful if the differences shown between bricks of the same class correspond to differences in furnace observations. For bricks with high spalling tendency the test has to be much less drastic if slight improvements are to be detected —*e.g.*, an air blast may be used for cooling.

The "simulative furnace test" to which reference is made elsewhere, is being used in this connection, and here the whole test furnace wall, built of the same or various bricks, is alternately heated and cooled. No test or calculation serves, however, to indicate positively the spalling tendency in any large-scale furnace results.

Slag Resistance.

There is no standard test of slag resistance, the difficulty being to reproduce faithfully all the factors contributing to destruction by slag. It seems likely that the "simulative furnace test" being developed in America will prove most satisfactory. In this, a small furnace is lined with bricks to be tested and fired by the method used in large-scale practice, if possible. The furnace may be rotated in order to reproduce "scouring action" of slag, and the slag may be introduced cold and melted with or without metal, or, as in tests of boiler furnace refractories, it may be introduced as a fine powder under pressure either through the burner or separate orifice.

The method is costly and lengthy, but seems capable of yielding valuable and accurate results. Simpler, quicker, and cheaper tests are—

(*a*) Melting the slag on the face of the test brick.

(*b*) Melting in pockets moulded or drilled into the brick.

(*c*) Melting in crucibles made of the brick mixture.

In all these are obvious objections, and furnace conditions are not reproduced. They give a broad indication, however, and are, therefore, useful, though a test will have to be standardised if it is to be really valuable to users in deciding on the suitability or otherwise of a brick.

Slag attack, or resistance, is both a physical and a chemical problem. The general principles governing selection of refractories are well known. A basic brick—*e.g.*, magnesite—for a "basic" slag; an acid brick, as silica, for "acid" slag; a chrome brick for ferruginous slags; sillimanite for highly alkaline dust and ashes, as yielded, for instance, by high-temperature wood fires.

Physically, slag attack can be viewed mechanically. Thus, if the constituent particles of a brick are only loosely held together, they are detached easily by moving viscous slag. If the brick is porous then thin slags, dust, and corrosive gases can easily penetrate. These, however, are only general conclusions, for, as mentioned earlier, in one case, at least, very porous, coarse, weak, friable, fireclay bricks (made on the high-grog principle) are proving excellent as boiler furnace linings. The results are difficult to explain, but it may be that the corrosive dust, etc., which first enters the face of the brickwork dissolves the surface of the particles, and is thereby increased in viscosity and refractoriness. The surface of the bricks would thus become cemented by a highly viscous, moderately refractory slag.

Slag attack may, to some extent, be reduced by the furnace user if he bears in mind the general principles underlying it, and adopts a fairly obvious precaution and one feasible in many cases—viz., to coat his brickwork with a thin layer of special cement or with a glaze which can either be produced by a mild flux or by a period of over-heating.

* See curves in article published January, 1930.

INSTALLING NEW EQUIPMENT.

By William Ashcroft.

It is frequently stated that keen competition quickens thought and facilitates concentration along channels likely to give favourable results in obtaining orders or contracts. Developments in tools and equipment are naturally examined with a view to improvement in the technique of production. In many instances, these developments not only increase production but improve the quality of the product; it is important, however, that any suggested equipment should receive very careful thought before installation is effected. Many factors must be considered before expenditure is incurred. Too often there is a tendency to install equipment in a department without having a thorough discussion on the merits of the particular form of equipment to be installed, and without a proper appreciation of its suitability in conjunction with other equipment in the department. The fact that so many improvements have been made during recent years in almost every type of mechanical appliance, both in regard to design and number of operations, makes it a necessity that a comprehensive knowledge of the capacity and the efficient working of a machine is obtained, either before or at the time it becomes part of the equipment of a department.

It is generally recognised that firms concentrate on the manufacture of certain types of equipment and spend an enormous amount of time in perfecting their specialities. They are continually experimenting and evolving complicated designs with the object of increasing the number of operations and generally improving the utility of the machine or plant, so that it is capable of effectively dealing with a wider range of work, or improving the performance of any single operation so that time occupied in doing suitable work can be reduced. Not infrequently, it is only after many years' experience on its special work, during which time improvements are gradually incorporated in the design, that a machine can be considered to approach more nearly to perfection.

When a special type of machine forms part of the equipment and is familiar, improvements will have been noted, and the installation of its most modern form will not incur operation difficulties; in such instances its increased utility will be appreciated. If, on the other hand, the modern machine is installed in a department in which its advantages are not realised, its usefulness will be confined to work for which a cheaper machine would be equally as efficient. Time spent in perfecting a machine is obviously wasted if full advantage is not taken of developments in design when operating it. Unfortunately, some manufacturers do not give service with their machines. Once a machine is sold no further consideration is given to it. This is a great mistake and should be guarded against. If the manufacturer has absolute confidence in his machine, and he makes sure it will not be misused, the results achieved will compare favourably with promises given prior to installation and will give satisfaction.

The Value of Service.

In the more advanced types of machines there is special need for organised effort to ensure that they are worked under conditions likely to give the best results, and resembling as closely as possible the methods whereby the operations were successfully carried out and demonstrated in the manufacturers' own works. Many of these machines are so complicated in design that a highly skilled operator is essential to obtain that degree of efficiency the machine is capable of yielding. Some makers of machines, who are sufficiently far-seeing to realise the importance of their machines being operated under the most suitable conditions, anticipate this need and arrange to send an expert to give definite instructions in the use of a particular machine.

When the machine is manufactured in this country, advantage can be taken of the fact by making sure that the particular uses of a machine will become familiar to those installing it and also to the operator who will be responsible for its proper working. As a rule, works departments have not the time to experiment with a view to finding out what a new machine is capable of doing; it is the duty of the manufacturer to know all possible operations, and to take every possible means of imparting the information to the buyer, with the most economical methods of applying the machine to the work it is designed to perform, in order that its success may be assured. Even after assistance has been given in this way, when the equipment is installed, it should be part of the manufacturers' business to make quite sure that the machine is being used as it was represented that it should be used in the first place.

The advantage of this form of service is not usually possible to a similar extent when the equipment is of foreign manufacture and supplied through an agent who may be fully acquainted with the possibilities of the machine, but unable to demonstrate them in practice. In such cases the buyer must take the risk and be prepared to experiment to a certain extent, so that the installation may become a profitable investment. This obviously means additional cost which, particularly in these stringent times, should be guarded against. In any case, additional cost involved in this way should be added to the cost of the equipment and should be considered as the monetary value of the service which ought to be given by the manufacturer.

Safety with Chemicals.

The Association of British Chemical Manufacturers and the Chemical and Allied Employers' Federation have decided to organise a chemical session in connection with the Safety Week of the National Safety First Association, to be held in Leeds from May 11-16. The morning of Tuesday, May 12, will be devoted to the cleaning and repair of vessels containing dangerous materials. Special attention will be given to the method of cleaning and repairing plant and vessels where it is necessary for workmen to enter a confined space in order to perform the allotted task, as these are the conditions under which accidents are most liable to occur.

The chair will be taken by Dr. E. F. Armstrong, chairman of the Association of British Chemical Manufacturers and of its Works Technical Committee, and the paper will be presented by Mr. J. Davidson Pratt, the general manager of the Association of British Chemical Manufacturers.

Personal.

Mr. Wesley Lambert, C.B.E., is relinquishing his position as manager of the metallurgical department of Messrs. J. Stone and Co., Ltd., after nearly 20 years' service with that firm. Formerly chief metallurgist of the Royal Gun Factories at Woolwich, Mr. Lambert has had extensive experience in both ferrous and non-ferrous work, and his services are in constant demand by the many technical societies with which he is associated.

It is understood that Mr. Lambert will continue to serve Messrs. J. Stone and Co. in an advisory capacity, and, while it is not his intention to seek further duties of a permanent nature his many friends will be desirous that his wealth of knowledge and experience will continue to be applied to metallurgical problems in industry.

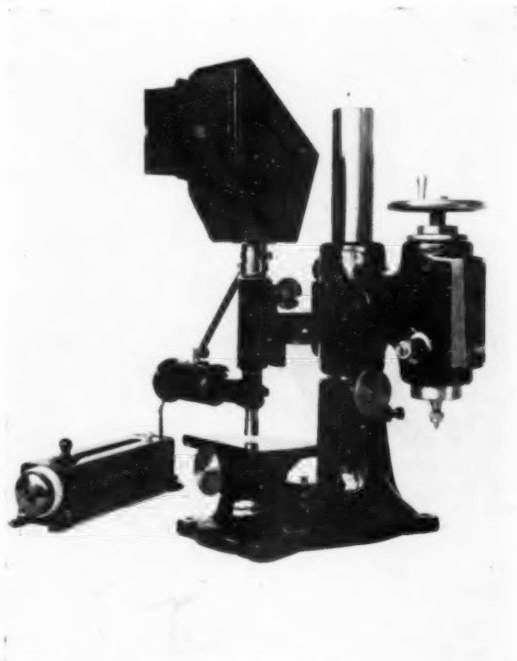
Dr. W. Rosenhain, F.R.S., has resigned his position as Superintendent of the Department of Metallurgy and Metallurgical Chemistry at the National Physical Laboratory, Teddington, a department which he initiated nearly 25 years ago. Dr. Rosenhain's contributions to metallurgical research have been many, and he has originated some remarkable advances in metallographic technique. He has displayed considerable interest in many research associations to which which scientific knowledge has been an asset. It is understood that Dr. Rosenhain will take up consulting work and his many friends will wish him success and many years of continued activity in the advancement of metallurgical science.

Mr. Colin Presswood has resigned his position as Technical Manager to General Refractories, Ltd., of Sheffield, a position which he has held since March 1925, and is prepared to consider offers for further engagement.

Recent Developments in Tools and Equipment.

THE FIRTH HARDOMETER.

As with other hardness-testing machines of the Brinell type, where the diameter or diagonal of the impression has to be determined, this measurement is made with the aid of a microscope, in which is fitted a micrometer scale. Whilst this provides a very accurate and ready means of measuring the size of the impression, it suffers from a certain disadvantage when numerous measurements have continuously to be made. On account of the "eye-strain" which frequently results from the continued use of the measuring microscope, the makers of the "Firth Hardometer" have for some time been considering ways and means of modifying the microscope measuring device with a view to obviating this disadvantage, and so considerably enhancing the value of this hardness tester. It was felt that if a magnified image of the impression could be projected on to a screen in such a way as to permit the operator "reading" the impression when comfortably seated, this would be a great advance over the method previously used. It would permit the operator to use both eyes in an unstrained position, and the greater ease of reading the impression would also speed up the process.



The Firth Hardometer.

On account of the high magnification of the microscope used with the "Firth Hardometer," however, serious technical difficulties had to be overcome to achieve this desideratum. These have now been satisfactorily dealt with, and a projector has been designed for use in connection with this instrument, which embodies the desirable feature outlined above.

The apparatus consists essentially of a light metal projector-head, which fits on to the eyepiece of the microscope, the interior of the head being provided with a plane mirror suitably positioned to reflect an enlarged image of the impression on to a hooded ground-glass screen which is fitted in the front vertical face of the head. The screen is marked with an accurately divided scale.

The requisite brilliance of illumination of the impression—and, incidentally, of the screen—is secured by a specially designed illuminator tube with adjustable reflecting prism carrying a special 6-volt lamp, which can be operated from the lighting mains through a suitable rheostat or resistance, and which is fitted to the lower end of the microscope tube just above the eyepiece.

The whole apparatus, as may be seen from the illustration, is of a simple character, sufficiently rigid without being in any way cumbersome, being so designed as to readily permit of the usual free handling of the machine, and the ease with which reading may be observed facilitates, to a marked extent, the ability to deal with successive impressions in a minimum period of time.

Notwithstanding the comparatively large magnification obtained, a satisfactorily sharp image of the impression, free from any trace of colour fringe or distortion, is readily secured on the screen, and the manipulation of the complete outfit is well within the competence of the average workshop operator.

Tests under average workshop conditions have confirmed the general utility of this hardometer, and in introducing it to the technical personnel of the engineering and metallurgical industries, it is confidently expected that the advantages conferred by it will readily be appreciated.

HIGH-SPEED MILLING CUTTERS.

The increasing use of rotary cutting tools, particularly in their application to milling machines, is causing manufacturers to devote much time to the development of these valuable tools. A notable example is the firm of Kendall and Gent, who have recently produced a side-and-face milling cutter and a grooving cutter having special features.

These cutters have been designed to give the maximum output from the best modern machines at their highest efficiency, yet at the same time they are economical, because of the number of times the cutters may be ground and, when the blades are worn out, the ease by which they can be replaced.

These cutters take the form of a body of high-tensile steel in which grooves are machined. Super high-speed steel blades of 18% tungsten alloy are made to fit the grooves formed in the body. The blades are fixed by a sweating process, which holds them so rigidly that they virtually form a solid cutter. This method of fixing, in addition to giving rigidity, enables the body of the cutter to assist in conducting the heat from the cutting edges of the blades.

The advantages of continuous helical cutting have been long established. In the grooving cutter shown in Fig. 1, double helical blades are inserted, and each blade is set at a quick angle, which gives smooth cutting and enables a number of blades to operate at one time. This special tool has another advantage in that it can be mounted on a suitable spindle nose and used for face milling, in addition to grooving. The outer edges of the blades can be shaped to suit the form of groove to be cut. This type of cutter has been designed for side and face milling, and is particularly suitable for machining grooves.

The side-and-face milling cutter shown in Fig. 2 has its blades located by means of half-round keys. These half-round shapes are machined from the body of the cutter, and the blades are shaped to possess this key. This method enables the blades to be located centrally, in which position they are sweated by a special process. Ample clearance

is provided to prevent cuttings clogging the cutter and marking the work. Both types of cutters can be accommodated to a wide range of work, and can be obtained in a variety of sizes or to suit particular requirements.

Fig. 1.—Grooving Cutter with double helical blades. *Fig. 2.—Side and Face Milling Cutter.*

THE SCLEROGRAPHE.

Considerable attention has recently been given to the measurement of hardness. In modern practice the tendency is to adopt apparatus by which the metal is submitted to a dynamic stress rather than a static load. This is probably due to the assumption that hardness is molecular energy, and the measurement of an energy implies the adoption of a dynamic process. Recent apparatus for this purpose, which leaves no appreciable imprint on the metal tested, enables testing of hardness much greater than that in respect of which ball testing is possible on account of the deformation of the ball. These new apparatus have the advantage of being able to measure superficial hardness obtained by case-hardening or nitration, as well as the degree of hardness involved by the rolling of thin sheet. In whatever system adopted, the new processes are designed to act on the metal point by point rather than by making impressions on the surface, and, consequently, the homogeneity of the metal can be taken into account. Tests are readily made at various points, and the results vary according to what constituent predominates at the point considered. In this way the results indicate the maximum and minimum hardness of the metal, and the mean hardness is readily deduced. With well-treated and very homogeneous metals the maximum deviation may not be more than 2 to 3%, but with commercial irons, cheap wrought-iron or badly-tempered or annealed pieces, differences of more than 10% may be found.

Methods of dynamic measurement find their full development in elastic reaction apparatus, in which hardness is measured by the rebound of an appropriate member in the interior of a guide, more or less elaborate, bearing a graduated scale. The principle consists in supplying the metal with a certain amount of kinetic energy and in measuring the amount of energy which the metal restores. The Rockwell apparatus operates on the principle of elastic reaction, as does the Shore scleroscope. A recent addition in this range of apparatus is the Sclerographe, by which hardness is measured from the height of rebound of a mobile body weighing 50 grms. falling from a height of 100 mms. The height of rebound automatically expresses the percentage of energy restored by the metal in relation to the energy received. This new apparatus, which is supplied by Messrs. C. F. R. Giesler, Ltd., Swinton House, Grays Inn Road, W.C. 1, has the advantage of enabling a variable height of fall. It is fitted with a clutch system, which is not easily deranged, permitting results being shown automatically on the millimetre scale. It is a portable apparatus, and can be carried in the pocket as easily as a slide rule. The measurements obtained by this instrument are readily converted into other systems.

NEW METHOD FOR THE PRODUCTION OF LOW-SULPHUR IRON CASTINGS.

As the result of several years' practical scientific research a very important new commercial process has been developed for the production of low-sulphur iron castings. The process is used in the ordinary cupola or open-hearth furnace. The new development enables the production of very high-grade castings with considerably lower costs of production.

The lowest produced pig iron with high sulphur content, with a very large proportion of old foundry scrap, can be used and the cheapest form high-sulphur coke.

High activity desulphurising agents are added in the cupola or furnace in a convenient form, by means of which the molten metal is thoroughly desulphurised. Sulphur is reduced from 0·15% or higher down to under 0·035% by the process. The method also has the advantage of enabling alloy additions to be made in the manufacture of special alloy irons, with practically no loss of the added alloy through oxidisation.

The method can be employed in any foundry; no special skill or additional plant is required. The process of deoxidisation is accomplished in the ladle by the addition of a special new type combination deoxidising alloy. The deoxidiser alloy is added to the molten metal in the proportion of 2 oz. of the alloy to each 1 ton of metal.

Castings treated by the addition of the new deoxidiser are produced absolutely sound and free from blowholes. When used in connection with intricate-shaped castings the treated metal takes an exceptionally clear definition of the mould. The surface of the castings is remarkably "clean faced," and the intricacies of shape are extremely clear and sharply defined. The machining costs are reduced due to cleaner surface castings.

By utilising the cheapest available raw materials the process brings about considerable economies in the manufacturing costs, yet at the same time the methods of refinement make an enormous improvement in the quality due to low sulphur limit and cleanliness of the finished castings, and freedom from blowholes through perfect deoxidisation.

The process is available on licence at reasonable terms to the whole trade. Licence to use the methods can be secured from Mr. Wilfred Hanby, Consulting Metallurgical Engineer, Talgarth Mansions, Baron's Court, London, W. 14. With the licence is given complete and detailed operating instructions.

Patina Steel.

The introduction of small percentages of copper in steel has long been recognised. The relatively high cost of stainless steels has directed attention to the possibilities of this element replacing the more expensive chromium. After much investigation a development of this character has been effected in Germany by which steel, having almost stainless properties, has been produced with copper as the alloying element instead of chromium. It is known as patina steel. It is claimed for this steel that, while it does not offer complete resistance to corrosion, it does not rust readily when exposed to air or when immersed for a time in water. In comparison with a straight carbon steel the loss of weight, from a test to which patina steel was subjected in sea water, was only 32%, against 54% for the carbon steel during the same period of test. It is further claimed for this steel that paint lasts much longer than on ordinary steel, and the cost is only slightly greater.

Some Recent Inventions.

APPARATUS FOR DETERMINING THE LIMITING CREEP STRESS OF MATERIALS.

Recent developments in the use of materials continuously subjected to stress under high-temperature conditions have necessitated special means for determining the ability of a given material to withstand the stress imposed without failure—*i.e.*, without undergoing any pronounced "creep" or "flow." The maximum stress which a material can withstand indefinitely at a given temperature is usually referred to as the "limiting creep stress."

The method generally adopted for the practical determination of limiting creep stress has the disadvantage of occupying considerable time, extending in some instances to several months, before a series of tests can be completed. An improved method, however, has recently been devised by which the limiting creep stress at any selected temperature can be determined by a single continuous test in a comparatively short time. One form of apparatus by means of which the method can be carried out is shown in elevation in Fig. 1. The apparatus includes a rigid rectangular frame, forming openings at the top and bottom. A round bar passing through the top opening fits neatly through a plate secured to the top of the frame. The bar has a feather and groove connection with the plate, which permits easy movement without rotation. The upper part of the bar is engaged by a nut, as indicated in Fig. 1. An anchorage bar passes through the bottom, and has a partly spherical bearing on a bottom plate. The apparatus also includes an intermediate connecting bar, and is associated with an electric furnace A, which can be set up in the position indicated.

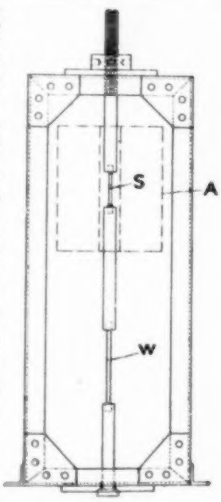


Fig. 1.

The method consists in connecting a specimen S to a "weigh-bar" W, subjecting both to a predetermined initial stress, the specimen being raised to the selected temperature, and maintaining these conditions until a state of equilibrium is reached. The "weigh-bar" W is a standard resilient body, the physical properties of which are known, and which serves throughout the test as a measure of the stress to which the specimen S is subjected.

The entire arrangement is such that, as the test proceeds, should the specimen undergo creep—*i.e.*, should it gradually stretch under the combined influences of stress and temperature, the stress proportionately and automatically decreases, the extent of decrease being indicated by the gradually decreasing length of the weigh-bar. Ultimately, a state of equilibrium is reached—*i.e.*, the weigh-bar ceases to show any appreciable further change of length,—and when this state is reached the stress to which the specimen is then being subjected is determined. It has been ascertained that this stress is the limiting creep stress of the material tested at the temperature maintained throughout the test.

339,890. David Colville and Sons, Ltd., of Glasgow, William Barr, of Hamilton, and William E. Bardgett, of Glasgow, patentees. H. D. Fitzpatrick and Co., agents, 94, Hope Street, Glasgow. December 18, 1930.

MAKING POINTED TUBULAR METAL ARTICLES

In making pointed tubular metal articles, such as hypodermic syringe needles by swaging, rolling, or drawing a tubular billet on a core of a metal capable of extreme elongation and retention of tensile strength, such as nickel-silver or brass, the cored tube is subjected to one or more heat-treatments so as to anneal the core and temper the tube whilst on the core. The core is subsequently removed. In one example, a brass-cored tube of an alloy sold commercially under the registered trade mark "Ni-chrome" is heated to 620° C. for 2 mins. to anneal the core and temper the tube. In another example as applied to carbon or stainless steels, and particularly to austenitic steels known as Firth's Staybrite steel, having from 17 to 12% of nickel and 8 to 12% of chromium, the cored tube is hardened by drawing, and then heated to 600° C. to anneal the core and temper the tube. A core may be chosen having a greater expansion by heat than the tube, so as to facilitate separation when cooled, and so as to promote the soldering or welding of the lining in case of a lined tube. Thus, a tube of high carbon or stainless steel or of an alloy which work-hardens but does not soften by heating below 750° C., and preferably one containing nickel, iron, chromium, molybdenum and tungsten, and known as "Contracid," may be heated on a core of nickel-silver or brass to from 600° C. to 720° C. to anneal the core and temper the tube. When heat-treating cored steel tubes containing a lining of incorrodible metal, as described in the prior specification, a cored carbon steel tube may be heated to 950° C. for annealing the core and soldering or welding the lining to the tube. The cored tube is then reheated to 780° C. and quenched to harden the tube, and then again heated to 300° C. to temper the tube. With tubes of steel sold commercially under the registered trade mark "F. H. Steel," the cored tube is heated to between 850° C. and 1,050° C. for annealing the core and uniting the lining. It may then be quenched and then reheated to between 150° C. and 250° C. to temper the tube. Instead of quenching and then reheating, the cored tube may be cooled to 900° C., and then water quenched, or to 950° C. and oil quenched, or to 1,000° C. and air cooled. After the heat-treatment the exterior may be polished, the points of the needles formed on the tube lengths by grinding, any necessary screw thread cut, and the tube plated with nickel, etc., before removal from the core. According to the Provisional Specifications a tube consisting of Ni-chrome on a brass core may be heated to 600° C. for 10 mins.

338,592. S. J. Everett, 939, London Road, Thornton Heath, Surrey.

A NEW ALUMINIUM ALLOY.

Aluminium alloys are produced which, although containing other constituents, may simultaneously contain thorium, nickel, and manganese. Another aluminium alloy has recently been developed which possesses valuable properties and which has an addition of an alloy of cerium and copper as well as the admixture of thorium, nickel, and manganese. A process of refining this alloy has also been devised.

The new alloy is extremely thin liquid, and can be cast to paper thickness in sand. The most complicated castings are claimed to be capable of production without blow-holes or shrinking holes. The strength of the castings made from this alloy varies, according to the thickness of the walls, between 16 and 22 kilogs. per square millimetre, and the strength of the material is increased by adopting the refining process. In addition to its homogeneous, fine crystalline grain, the alloy is remarkable for its extremely high resisting properties against acids, saline solutions, and sea-water. These properties permit of an extensive working of the alloy in cast and rolled form. The material produced from the alloy practically does not oxidise, is clean, and does not mark. It can be easily rolled, and in rolled condition attains a strength of 40 to 45 kilogs. per square millimetre, with expansions of 11 to 15%. Plates may be rolled from the alloy in any length and width without edge-cracking, and without soiling the rolls. Of particular importance is the fact that the scrap may be repeatedly melted down, and the quality of the material is considerably improved thereby, in that it becomes more and more homogeneous. The alloy may be used with great success for splash and chill castings, as the thin liquidity allows the

most complicated castings to be made with a high degree of accuracy. If 1·5% nickel be added to the new alloy the shrinkage is reduced to such an extent that the alloy is suitable as material for pistons of internal combustion engines. With suitable percentages of nickel and thorium, the alloy has given excellent results as pistons for steam-engines, air and liquid pumps up to 14 atm. pressure above atmospheric, up to the most complicated constructions. The admixture of thorium increases the critical recrystallisation temperature, so that hot-stressed roller materials may be subjected in work to higher temperatures without any danger of hot brittleness by reducing the strength properties. The alloy has the following composition :—Nickel, 0·3 to 1·5% ; thorium, 0·05 to 0·9% ; copper-cerium alloy up to 6·8%, with a copper content of about 90% ; manganese, 0·4 to 0·8% ; the remainder aluminium with the usual commercial iron-content tolerances.

The processes for the refining of this alloy consist in that the alloy is quenched from a temperature of from 5·35 to 480° C. to room temperature in a barium chloride bath, and is then submitted to a heating treatment varying between 300 and 50° C. These variations in temperature depend less upon the actual composition of the alloy than upon the strength and expansion. Different tempering heats are selected, as strength, expansion, and tempering heats are dependent upon one another, and as it is possible to give the alloy a strength and expansion of a certain value determined by the use of the alloy for the actual constructional purpose. In the case of an alloy with a nickel content of 1% and thorium content of 0·2%, a temperature of 180° C. should be chosen.

339,469. Otto Kamps, of Emmich-strasse, Aachen, Germany, patentee. Messrs. Chatwin and Co., agents, 253, Gray's Inn Road, London, W.C. 1.

ANNEALING CRYSTALLINE SUBSTANCES MAGNETICALLY.

The mechanism of work-hardening, when metal is deformed by cold work, is believed to be connected with the distorted space lattices adjacent to the slip planes and the secondary hardening resulting from ageing. A new annealing process has for its object a rearrangement of these space lattices by subjecting them to the action of a magnetic field, or like etheric flux or vibration, other than heat, having a relative movement with respect to a substance, as distinguished from a reversal of stress obtained in an alternating field without other relative movement.

In one way of carrying out the process a magnetic metal, such as iron or steel, which has been work-hardened or super-hardened by deformation, is placed in a strong magnetic field, so that it becomes magnetically polarised in a certain direction, and the position of the metal is then changed with respect to the magnetic field, or the direction of the magnetic field is changed relatively to the metal, so that the direction of polarisation of the metal is changed. This may be effected by revolving the article to be hardened while it is in the field of the magnet, or by passing the article through a solenoid while an alternating current is passing through its coils ; the effect being to place the article in, or in the case of wire, rod, or tube, to pass it through an alternating magnetic field, or a magnetic field whose direction changes in relation to the metal.

This magnetic annealing process is specially applicable to magnetic materials, such as iron and steel, which have previously undergone a process of mechanical deformation whereby the space lattices are distorted ; but metals not usually classed as magnetic are known to offer resistance to the passage of magnetic flux, such resistance varying with the characteristics of the metal and with its physical condition. It is, therefore, possible by magnetic fluctuations of sufficient violence to exercise stress on the atomic structure of non-magnetic materials and thereby to induce a useful rearrangement of the atoms.

338,511. E. G. Herbert, West Didsbury, Manchester, Patentees. Messrs. Wilson, Gunn and Ellis, Agents, Market Street, Manchester. Accepted Nov. 17, 1930.

Report of Departmental Committee on Patents and Designs Act.*

The report of the Departmental Committee on the Patents and Designs Acts and practice of the Patent Office has just been published. The Committee was appointed by the Board of Trade in May, 1929, to consider and report whether any, and if so what, amendments in the Patents and Designs Acts, or changes in the practice of the Patent Office are desirable. In the course of the inquiry the Committee heard oral evidence by witnesses representing a number of associations, companies, Government Departments, and also from witnesses on their own behalf ; while a large number of observations and suggestions in writing were received.

According to the report, the Committee find no general demand for alteration of the basic principles underlying the existing law in this country in relation either to patents or designs, but recommend a large number of amendments in the Acts, some of which they regard as important, and such as to justify early legislation. Among the more important of these recommendations are :—

An extension of the area of the official search as to the novelty of inventions for which patents are sought. The Committee recommend the adoption of a scheme by which the statutory duty now imposed upon the Patent Office of searching through the specifications of British patents published within the previous fifty years should remain, but the search would not necessarily be restricted to those documents. The examiners would be at liberty, acting under the directions of the Comptroller, given either generally or in any particular case or class of cases, to make search in any other documents (including foreign specifications) or books which might offer any prospect of containing anticipations of the invention in question. The Committee came to the conclusion that such a search, under well-informed direction, would be as adequate and useful as that undertaken by any other country.

Drastic amendments of Section 32A (which deals with the power of the Court in infringement actions to grant relief in respect of particular claims) in order to avoid or mitigate the difficulties and abuses that have arisen as a result of the enactment of the section by the Patents and Designs Act, 1919.

The strengthening of the law relating to groundless threats of legal proceedings in regard to patents.

And amendment of the law in order to remove the grievance which exists among inventors in the fields of chemistry, medicine, and food, that invention in these fields is being unduly hampered by reason of the operation of Section 38A (1) of the Acts.

The appointment of a judge of the High Court as the tribunal for hearing those appeals from the Comptroller in patent cases that are now heard by the Law Officer. The Committee further recommend that the persons who at present have audience before the Law Officer should have audience before the judge, and that these changes should not constitute High Court proceedings.

Among the more important proposals which were placed before the Committee in evidence, but which they do not recommend for adoption, included a proposal to introduce into the industrial property laws of this country a new form of monopoly in respect of "useful designs" or so-called "short-term patents." The conclusion of the Committee is that the risks of hampering industry outweigh the possible advantage from such a form of protection.

In regard to another proposal, that the jurisdiction of the Comptroller should be extended in order to enable him to try comparatively simple patent actions in regard to infringement and invalidity, the majority of the Committee is opposed to the suggestion, but a substantial minority favours such an extension of the Comptroller's jurisdiction, mainly because of the need for providing some less costly method of settling disputes relating to patents than at present obtains.

* *Copies obtainable from H.M. Stationery Office, price 1/6.*

Refined Pig-Iron Production

New Process Cast Iron.

ONLY those associated with special pig-iron production know the strides that have been made in recent years in the improvement of the strength, toughness, resistance to shock, texture, and degasification of high-duty pig iron. This was partly necessitated by the advent and general acceptance of the Diesel and high-speed internal combustion engine, as pig iron that had given good results for steam-engine castings was found to be totally inadequate for this class of work.

It will, therefore, be found particularly gratifying to our readers who are engaged in the production of high-duty grey iron castings and malleable iron, that Messrs. Sir W. G. Armstrong Whitworth and Co., Ltd., after a great amount of research and investigation, have installed plant at their Close Works, Gateshead-on-Tyne, that enables the production of the highest class of special high-duty iron.

During recent years, several processes for the improvement and refining of pig iron have been investigated by the staff at Close Works, but the advantages of most of these new methods were found to be limited. The principal drawbacks were as follows :—Firstly, the intimate contact of the metal with the fuel, and the resulting absorption of deleterious elements into the iron. Secondly, the lack of complete control of the atmosphere in the furnace, with the ensuing dangers of oxidation.

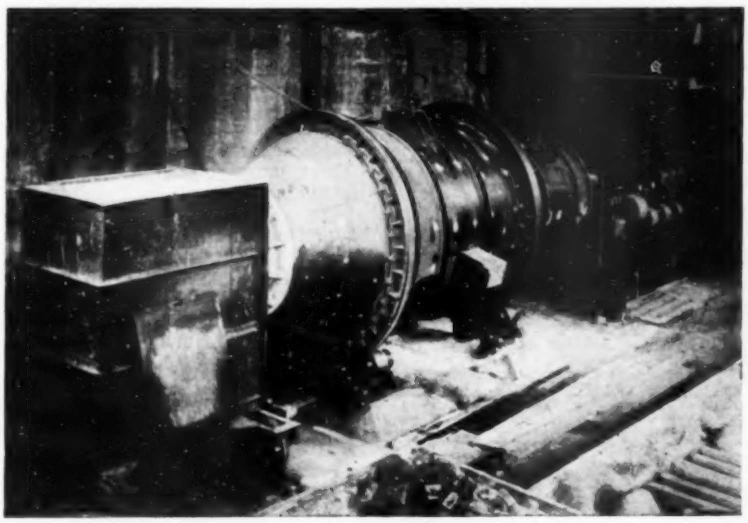
The rotary type of furnace for melting cast iron was thoroughly investigated last year by Messrs. Sir W. G. Armstrong Whitworth and Co., Ltd., and eventually a furnace of the Sesci type was installed. This has now been working for some months, and most remarkable results have been obtained.

The principle of the rotary furnace is not new. It is in the application of the pulverised fuel, the shortness of the flame, the concentrated intense heat, and the efficient preheating of the combustion air by the exhaust gases, that this type of furnace showed great advantages. In the short time that it has been working the results already obtained promise to revolutionise accepted views of the quality, strength, and resistance to wear of grey cast iron. The furnace also presents outstanding advantages in the manufacture of malleable pig iron and malleable iron for casting.

Before illustrating the advantages derived from a furnace of this type, it may be of interest to the reader to obtain an insight into the appearance and working of this unit.

As will be seen from the illustration in Fig. 1, the furnace consists of a strongly reinforced steel cylinder, refractory lined, lying horizontally on two roller paths. The furnace is rotated by means of a variable-speed motor, with reduction gear and chain drive. A special controller allows this movement to be regulated from a gentle oscillation at slow speed while the charge is cold, to a full revolution in either direction as melting proceeds. The burner rotates with the furnace, and has been designed to use coal low in volatile matter, with the corresponding advantages of such a type of fuel. Combustion takes place at the base of the burner, and is complete before the cylindrical portion of the furnace is reached. At the other end of the furnace a movable exhaust box allows the exhaust gases to pass from the furnace into the flues. This exhaust box is mounted on an electric bogey, so that the furnace can be uncovered for charging in a few seconds. After passing into the flue, the exhaust gases are directed by a by-pass either to the recuperator or chimney, in accordance with the working of the furnace. The recuperator is an outstanding factor in the efficiency of this furnace, as it is instrumental in obtaining a very high melting temperature, and of regaining approximately 30% of the calorific power of the fuel used.

Fig. 1. Rotating Furnace for melting cast-iron. It is rotated by means of a variable-speed motor, with reduction gear and chain drive.



The application of pulverised fuel, short flame, concentrated heat, and efficient pre-heating, shows great advantages.

The plant also embraces a motor-driven, water-cooled, charging machine : a pulveriser for grinding the coal to the required fineness, and a positive blower for supplying the exact amount of air for perfect combustion.

As both the supply of air and fuel can be carefully and accurately regulated, perfect control of the atmosphere of the furnace can be obtained. The complete mechanism of the furnace comes under the control of one switchboard.

From the foregoing description, the reader will himself have formed some idea of the advantages to be gained by this method of refining, but a short comparison is given below of iron turned out from this furnace with iron manufactured in old type furnaces. Firstly, through the rotating action of this furnace and the possibility of superheating the iron without fuel contamination, an iron is

obtained wherein the graphite is in a perfectly fine disseminated condition. As is generally known, graphite, owing to having little or no strength in itself and being comparable to a crack or cavity, is one of the principal weakeners of cast iron. It will, therefore, be understood that an iron, such as is produced by the new process, wherein the graphite is very fine and extremely well disseminated through the mass, is most advantageous for work that has to withstand pressure, resist shock or heavy load.

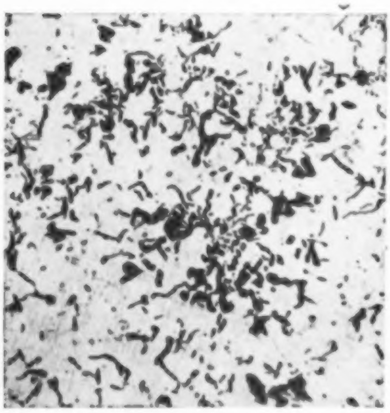


Fig. 2. Structure of good quality cast iron by previous method.

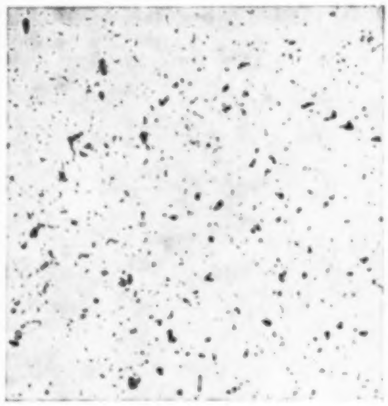


Fig. 3. Structure of cast iron from New Process Pig-iron.

Photomicrographs shown in Figs. 2 and 3 illustrate the graphite magnified to 100 diameters, of a good quality cast iron turned out by previous practice in comparison with this new process pig iron. The latter photomicrograph is of special interest, as it was taken from a sample cut from a Diesel-electric cylinder head cast from new-process pig iron. This iron was extremely tough, gave a tensile strength of 20·6 tons per sq. in., and yet was quite machinable in the thinnest sections of this casting, which approximated to a quarter of an inch. This casting was purposely made from new-process pig iron, as owing to its varying section it was a difficult foundry proposition, and was cast without any recourse to chilling. On being sectioned where one would normally expect trouble through open grain, shrinkage, etc., and being minutely examined, it was found to be perfectly solid and to exhibit a perfectly uniform grain through all thicknesses. This latter point cannot be too much stressed, as ordinary cast iron is extremely unreliable owing to its strength and physical characteristics being so affected by section thickness. This is apparent in most iron castings, and it can be seen that in any one casting the "grain" of the metal changes in accordance with the section, whilst one of uniform thickness shows open towards the centre.

The rotating action of the furnace, with the ensuing turbulence of the molten bath, also ensures complete degasification of the iron. This gives better casting qualities, greater solidity, and allows the metal to solidify quickly without any undue evolution of dissolved gases. Furthermore, degasification improves the strength of the iron from 20 to 30 per cent., as it is believed that this removes the gaseous films surrounding the grain boundaries.

The mechanical mixture obtained by the working of this furnace ensures a perfectly uniform and homogeneous pig iron. This advantage will quickly be appreciated, especially in the case of alloy iron, where it is essential that the alloy should be evenly disseminated through the mass.

This furnace, as in open-hearth practice, allows the manufacture of pig irons low in carbon and sulphur. This is of special interest to the malleable trade; the chief advantages of the new-process pig iron for the manufacture of malleable iron are given below:—

1. Lower carbon in complete solution during manufacture with balanced silicon content gives quicker annealing time.

2. Iron on annealing shows extremely fine, well-disseminated, nodular graphite, giving extremely tough malleable, with high resistance to shock.

3. Low sulphur giving a better "malleable" malleable, particularly shown by high elongation on tensile test.

4. Low sulphur, giving a less stable carbide, with saving in annealing.

5. Less shrinkage in finished castings owing to the range of analyses offering a correct control of carbon and silicon contents.

6. Degasification giving good castability and soundness.

7. Guaranteed analysis to specification.

In a later issue comprehensive data will be given of the high strength, resistance to shock, singular freedom from cooling conditions, resistance to pressure, and other advantages obtained by this new process pig iron, and it is interesting to note that Sir W. G. Armstrong Whitworth and Co., Ltd., are supplying large quantities of this new-process iron to users both at home and abroad, and welcome inquiries for this brand to any practical specification.

Progress in Metallurgy.

At a general meeting of the Deutsche Bunsen Gesellschaft für angewandte physikalische Chemie, to be held in Vienna from May 25 to 28, 1931, the subject of a symposium will be "Recent Progress in the Science of Metallurgy, with Particular Reference to Light Metals." A member of the Institute of Metals, Geheimrat Professor Dr. H. Specketer, director of the I.G. Farbenindustrie A.-G., and managing director of the Griesheim Elektron Works, is in charge of the arrangements for the Symposium. A large number of papers will be presented, including the following:—"Technical Advances in the Sphere of Electro-chemistry," by J. Billetter, of Vienna, who will also present a paper entitled "The Present Position and Prospects of the Electro-chemical Industry"; "The Lime Law of Transformation of Deformed Metal," by F. Sauerwald, of Breslau; "Di-pole Moments of Inorganic Compounds," by H. Ulrich, of Rostock; "Cinematographic Representation of the Recrystallisation of Rock Salt," by K. Przeban, of Vienna; "Electrolytic Chromium-plating of Light Metals," by A. Koenig, of Karlsruhe; "The Formation of Sulphide Layers on Silver considered with regard to Oxidation of Metals," by K. Fischbeck, of Tübingen; "The Technology and Applications of Electron Metal," by W. Schmidt, of Bitterfeld; "Electrically Prepared Oxide Films in Aluminium," by H. Röhrig, of Lautawerk.

Travelling Scholarship.

The examination for the Dorman Long Travelling Scholarship will be held at various centres on June 20 this year. This scholarship, which has a value of £300, is awarded every three years on the results of a practical examination; it is designed to develop the knowledge and use of steel-frame construction in this country. In order that the younger members of the profession may have a chance of distinction, the age of candidates has been limited to 30 years. The main outline of the examination is this: Each candidate will be given a set of framing plans and a pillar schedule, and will be required to provide shop detail drawings, mill order sheets, specification, and cutting lists for use in the fabricating shop. Twenty-one days will be allowed, after the sitting, for candidates to submit finished drawings and lists. This year's winner of the scholarship is to travel Canada and study building conditions over there.

Business Notes and News

The British Aircraft Industry.

It is interesting to note that the British aircraft industry seems to be building up a large foreign business, many consignments of machines and parts being exported every year. Export figures for 1930 show that, although there was a drop of about £130,000 below the 1929 figure, there was an increase of £850,000 over the value for 1928. The total was approximately £2,000,000. It may be argued that this trade went to the Colonies and the Dominions, but it is not so, for there are now more than 20 countries using British aircraft for military and civil purposes. Several large orders for military 'planes were received last year, notably for Greece and Belgium. Norway, Sweden, Spain, Siam, Mexico, Portugal, Argentina, Russia, and Chile are among other customers. The " Bristol Bulldog " (built by the British Aeroplane Co., Ltd., Bristol) alone is used in nine countries, and this, of course, is a product of only one of the many manufacturers who have had considerable success in exporting their machines.

In this connection it is interesting to note that an order has quite recently been placed by the Finnish Government for 13 Armstrong-Siddeley Jaguar-Major engines for the Finnish Air Force.

Recent developments in the design and production of medium-sized transport and light " limousine " 'planes have resulted in an increased overseas market for these machines rather than for the light sporting and training types which once formed the greater part of British aircraft export.

While numbers of these machines are going out of the country there is an ever-growing demand for them at home. Figures have shown that each British transport machine was flying more than double the average mileage per year flown by German and American machines; while the average load carried by each 'plane was ten times greater than that carried by French, six times that carried by American, and about two and a half times that carried by German machines.

Every year brings new developments, and aircraft constructors are always looking ahead with a view to producing aircraft of greater comfort, higher speed, and increased carrying capacity.

Iron and Steel Production.

The production of pig iron in the United Kingdom fell from 337,000 tons in January to 318,200 tons in February, although the daily output in the latter month showed an increase of 5 per cent. The number of furnaces blowing declined by two to 81, and the production of various kinds of pig iron from these furnaces was, according to the *Bulletin* of the National Federation of Iron and Steel Manufacturers, 82,400 tons of hematite, 122,900 tons of basic, 86,900 tons of foundry, 13,700 tons of forge, and the remainder consisting of alloy and other qualities. The production of steel increased from 402,200 tons in January to 486,400 tons in February, and consisted of 121,800 tons of acid open-hearth steel, including 2,200 tons of castings; 343,000 tons of basic open-hearth steel, including 400 tons of castings; and 21,600 tons of other kinds of steel ingots, including 6,900 tons of castings.

Imports of iron and steel declined to 177,100 tons, but although this is the lowest figure since February, 1929, imports were for the sixth month in succession in excess of exports. This decline in exports is to a great extent due to the dislocation of some of Great Britain's markets for iron and steel. According to the trade returns, the exports to the Argentine, India, and Ceylon, Australia, Japan, and New Zealand have been reduced very considerably.

Test for Electrical Apparatus used in Mines

The testing of electrical apparatus used in mines has been unofficially carried out at Sheffield University. The object of these tests is to determine by actual explosion experiments whether the electrical apparatus under test is flameproof, or, in other words, to determine whether the construction is such as to prevent the ignition of firedamp within the apparatus from giving rise to an explosion of firedamp outside it. Although the normal conditions are considered sufficiently safe to permit the use of electricity in mines, it is necessary to take suitable precautions and official tests are now to be made. A new testing station for this purpose, situate at Harpur Hill, Buxton, is expected to be in operation this month. In view of these official tests the University of Sheffield has decided to discontinue this work.

Progress in use of High-frequency Furnaces.

It is noteworthy that the order recently placed with the Electric Furnace Co., Ltd., for a 28-cwt. Ajax-Northrup high-frequency furnace for a French firm, is a repeat order, as this firm had already in operation one 28-cwt. and four smaller furnaces of the same type. Recently a 28-cwt. furnace lining, made by the Rohn process, produced 228 heats for an average power consumption of 622 k.w.-hrs. per ton (1,000 kg.). These results, obtained when making alloy steel from good, raw material, prove the economy of the process. The complete plant will have a capacity of about 20 tons per eight-hour shift, and is by far the largest installation of high-frequency furnaces yet made. It is indicative of the progress being made in this country that almost the whole of the equipment has been, or will be, manufactured in Great Britain.

Since the first commercial Ajax-Northrup furnace in this country was erected, three and a half years ago, 28 of these furnaces of from 100 to 650 k.w. each have been supplied by the Electric Furnace Co., Ltd., in England and France. The rate of progress of this method of melting has thus been exceptionally rapid in spite of the continued depression.

Competition of Industrial Designs, 1931.

By kind permission of the Board of Governors of the Imperial Institute, the public exhibition of works sent in for this year's open Competition of Industrial Designs organised by the Royal Society of Arts will be held in the Exhibition Pavilion of the Imperial Institute, South Kensington, S.W. Full particulars of the Scholarships and Prizes offered by the Society, City Companies, well-known manufacturers, and other bodies, for designs for Architectural Decoration, Textiles, Furniture, Book Production, Memorial Tablet to R 101, Electric Light Fittings, Silverware, Leather Work, Posters, Showcards, etc., can be obtained from the Secretary of the Royal Society of Arts, Adelphi, London, W.C. 2. Application for forms of entry, labels, and instructions must be sent to the Secretary of the Society between May 1 and May 9, and the last day for receiving entries is May 22. The designs entered for the Competition will be received at the Imperial College of Science and Technology, Imperial Institute Road, South Kensington, S.W., between June 8 and June 10, and after the judging, which takes place in July, the prize and accepted designs will be exhibited to the public at the Imperial Institute from August 1 to August 31 (Sundays included).

The arrangements and schedule of Prizes for the 1932 Competition will be considered in September next, and several other important firms have already notified their intention of offering prizes in connection with it.

Harder Steel for Railways.

A new specification has been prepared for steelmakers to produce a rail of greater hardness and resistance to abrasion than has been customary. The need for a harder rail steel has been recognised, but the difficulty has been to overcome the brittleness to which harder steels of this type are subject. The general specification which contains 0·5% carbon, 0·1% silicon, 0·8% manganese, and very low percentage of sulphur and phosphorus is quite suitable for rails on quiet branch lines, but in busy sections they require to be frequently renewed, in some instances as often as every nine months. It is in these busy sections that the greatest dislocation to traffic occurs when a length of rail has to be replaced, and it is for this reason that investigations have been in progress to produce a steel with longer wearing qualities.

The new specification, which is said to contain a higher percentage of manganese than has been customary, has been prepared by Mr. C. J. Brown, chief engineer of the London and North-Eastern Railway Company. Steel of this specification has been subjected to exhaustive tests with satisfactory results, and it is stated that the North-Eastern Railway Company has decided to adopt the new steel as a standard for rails.

Railway Materials for China.

It is possible that large orders for British railway materials will be placed by China in the near future. For this purpose it has been decided to appropriate part of the £4,000,000 now in the Hong Kong Bank in London, and the Chinese Ministry of Railways has already sent a representative to England to confer with the London purchasing commission. This is Dr. Wang Chin-Chun, who arrived in London on March 30. Dr. Wang was formerly managing director of the Chinese Eastern Railway.

Industrial Campaign on the Tyne.

Newcastle-on-Tyne is organising a big campaign to improve both shipping and industrial conditions in the Tyneside area. It is claimed that ships can be accommodated from end to end of the 19 miles of navigable waterways, and the Tyne Improvement Commission has been seeking to improve this accommodation. Progress was made in 1927, when a new "swinging area" was made for vessels up to 450 ft. in length, while in 1928 a new riverside quay was completed and opened for trade; this quay, which is at the Albert Edward Dock, is 1,100 ft. long, with a depth of 30 ft. at low water.

It is now intended to provide 3,000 or perhaps 4,000 ft. of open-water quays at Jarrow Slake, which is a stretch of land (nearly 200 acres) covered by shallow water. This will entail the dredging of the Slake, to provide a low-water depth of 35 ft.; the first part of the work of making this stretch useful to shipping will cost about £1,000,000.

In addition to these developments, the Commissioners intend to acquire, if possible, the Tyne Dock, at present owned by the L.N.E. Railway Company, thereby bringing the administration of the whole river under one authority.

While these negotiations are going on with regard to the river, another body, the Tyneside Industrial Development Board, is seeking to obtain for the district a larger proportion of the country's trade. With the intention of attracting to the district industries other than the coal, shipbuilding, and heavy engineering industries, which have hitherto been concentrated there, the Board has issued a series of attractive folders to be sent out to all parts of the world. The main advantages of the district, as set out in these folders are :—Situation in the centre of a coalfield, with cheap supplies of coal, oil, electricity, water, gas, and chemicals; excellent shipping facilities; cheap port dues; ample supply of labour; and the fact that it is a distributing cenıre for a population of from 2,000,000 to 3,000,000.

A large amount of information has also been collected with regard to vacant buildings, sites, etc., and all other items which might interest prospective new companies.

The work of the Board has, so far, been restricted to its original area, but the Government has recently announced an intention of trying to set up a North-East Coast Development Board, to cover Northumberland, Durham, and the Cleveland area of Yorkshire. The Tyneside Board has endorsed this plan and will co-operate in an industrial survey of the whole area.

It is interesting to note that the first shipbuilding order on the Tyne this year has been booked by Messrs. Swan, Hunter and Wigham Richardson, Ltd., Wallsend. It is for a 6,000-ton tanker for the Burma Oil Co., Ltd., Glasgow, and has come at an opportune time, for there are only five vessels left on the stocks on the Tyne.

Mineral Production of the United States in 1930.

The estimated total value of mineral products in the United States in 1930 was approximately $4,795,000,000, as announced by Scott Turner, Director of the United States Bureau of Mines, Department of Commerce. This is a drop of about 18% from the total value of mineral products in 1929.

Declines in values, accounted for both by lower unit prices and by the falling off in output of nearly all mineral products, are principally explained by the depression prevailing during the year in most lines of industrial activity. The total value of metallic products in 1930 decreased about 33% as compared with 1929. Notable decreases in total values, ranging from approximately 25 to 50%, were recorded for copper, iron, silver, lead, and zinc, but the value of gold production increased slightly. The total value of non-metallic mineral products in 1930 decreased about 15% from the preceding year. Of the mineral fuels, the total value of natural gas increased, while the total values of bituminous coal, natural gasoline, and petroleum recorded sharp declines.

The following figures give the estimated total value of metallic mineral products and non-metallic mineral products other than fuels, and of mineral fuels produced in the United States in 1930.

Estimated Value of Mineral Products of the United States, 1930.

Metallic	$985,000,000
Non-metallic (other than fuels)	1,028,000,000
Mineral fuels	2,782,000,000
Total	$4,795,000,000

Metallurgists' Conference in Switzerland.

Switzerland will be the scene of this year's Autumn Meeting of the Institute of Metals. It is being held in Zürich from September 13–18 by kind invitation of the Schweizerische verband für Materialprüfung. The evening of September 13 will be devoted to the formal opening of the meeting, addresses of welcome by the inviting body and the Autumn Lecture. The latter is to be given by Mr. U. R. Evans, M.A., on "Thin Films on Metals in Relation to Corrosion Problems." After the Lecture an entertainment will be given in the Great Hall of the Zürich Polytechnic.

The mornings of September 14 and 15 will be devoted to the reading and discussion of papers, whilst for the afternoons visits have been provisionally arranged to the works of Messrs. Escher, Wyss and Co., Zürich; Maschinenfabrik Oerlikon, Oerlikon; Messrs. Brown, Boverei and Co., Baden; Messrs. Sulzer Brothers, Winterthur; Kraftwerke Wäggital, Wäggital; Messrs. Eisen and Stahlwerke vorm. G. Fischer, Schaffhausen; and Messrs. Alfred J. Amsler and Co., Schaffhausen.

A Ladies' Committee is arranging visits by the ladies of the party to the Kunsthaus, Uetliberg, Landesmuseum, and the Wäggital.

In the evening of September 14 members and their ladies will be the guests of the City and Canton of Zürich at one of the hotels on the heights above the city, whilst for the next evening an excursion by steamer on Lake Zürich, followed by a dinner and dance at a lakeside village, is being arranged.

On September 16 an excursion will take place to the Rigi, the party going thence by steamer to Lucerne, where the night will be spent.

On September 18 the main party will divide, one going to Biel to visit a watch factory and leaving for England in the evening, whilst the other will go viâ Lötschberg to visit the new aluminium alloys rolling mills at Chippis-Siders in the Rhône Valley. From Chippis members will either return to London viâ Lausanne or Geneva, or proceed viâ the Simplon to Milan to take part in the International Foundry Exhibition and Congress, which continues at Milan until September 27.

During the week preceding the Institute of Metals Meeting there will be held, also in Zürich, the first congress of the New International Association for Testing Materials; thus, inclusive of the Milan congress, there will be taking place in Switzerland and Italy during September a series of meetings covering three weeks. In view of the fortunate juxtaposition of these important international gatherings, it is expected that they will be largely attended by metallurgists and engineers from all parts of the world.

Further particulars may be obtained on application to Mr. G. Shaw Scott, M.Sc., 36-38, Victoria Street, London, S.W. 1.

Firth-Brown's Fusion.

Messrs. Thos. Firth and Sons have issued a circular containing full particulars of their recent fusion of interests with John Brown and Co., Ltd. The formal amalgamation of these two famous Sheffield concerns took place on March 31. Except for the shipbuilding and colliery activities of Messrs. John Brown and Co., the operations of the two firms will henceforth be continued jointly under the name of "Thos. Firth and John Brown, Ltd." As stated in the circular, for many years there have been close relations between the two neighbours, and already considerable co-operation has taken place in certain works services. The actual arrangement of the fusion is as follows:—John Brown's works at Sheffield and Scunthorpe have been transferred to Thos. Firth's to be operated in conjunction with the Norfolk and Tinsley Works. While changing their name, Firth's have increased their share capital to £2,450,000, and transferred their registered office to Atlas Works, Sheffield. Browns, likewise, have their registered address at Atlas Works, but they will continue to carry on, under their own name, their shipyard at Clydebank and their collieries in South Yorkshire. Hence, the new combine will comprise the whole of the present undertaking of Thos. Firth and Sons, Ltd., and also the Atlas and Scunthorpe Works of John Brown and Co., Ltd. The same production and sales organisation as before will be maintained to the utmost extent. The Board consists of the following :—The Hon. Henry D. McLaren, C.B.E. (Chairman), Mr. F. C. Fairholme and Mr. A. J. Grant (Joint Managing Directors), the Right Hon. Lord Aberconway, P.C., Sir Charles E. Ellis, G.B.E., K.C.B., Mr. Edward Dixon, O.B.E., Mr. Percy W. Fawcett, O.B.E., Mr. E. Willoughby Firth, Mr. John C. Firth, Mr. Chas. F. Spencer.

Some Contracts.

The Electric Furnace Co., Ltd., has received an order for a 28-cwt. Ajax-Northrup high-frequency furnace for a French firm. Orders have also been received for high-frequency furnaces for two Sheffield steel works. The motor generator supplied with one of these furnaces will be the largest installed in this country, and will be equipped with furnaces of 5, 10, and 18 cwt. capacity.

The British Thomson-Houston Co., Ltd., Rugby, has obtained repeat orders from the London Electric Railway Co. for 17 mercury-arc rectifiers of 1,500 kw. each, and 5 of 2,000 kw. each, to be installed in nine sub-stations. Other B.T.H. equipment at these sub-stations will include over 100 air-blast transformers, 120 high-speed circuit breakers, and 60 heavy-duty oil-circuit breakers. The rectifiers will be provided with automatic control gear for remote operation. Two 1,200 kw. B.T.H. rectifiers have also been ordered by the L.M.S. Railway Co. for the Barking-Upminster electrification scheme, while one will soon be put into operation on the Manchester-Altrincham Railway.

The following orders have been placed with British firms by Soviet trade organisations in this country:—Supply of £200,000 worth of electrical equipment for blooming and rail mills, Metropolitan-Vickers Electrical Co., Ltd.; boiler plant to the value of £50,000, Babcock and Wilcox, Ltd.; tin plates to the value of £73,000, the South Wales Tinplate Corporation; supply of £100,000 of steel wire, Brunton's, of Musselburgh; supply of machine tools to the value of £100,000, Alfred Herbert, Coventry; and extension of the existing agreement with Associated British Machine Tool Makers, Ltd., from £600,000 to £1,000,000.

The Metropolitan-Cammel Carriage, Wagon, and Finance Co., Ltd., Saltley, Birmingham, has received an order from the Rhodesia Railways for two eight-wheeled well wagons, with a carrying capacity of about 40 tons over the whole of each wagon and a maximum of 30 tons in each well.

Sir Lindsay Parkinson and Co., Ltd., Blackpool and Shaftesbury Avenue, W.C. 2, has received from the Crown Agents for the Colonies a contract for harbour extension work at Famagusta, Cyprus. The contract is valued at £200,000.

The Egyptian State Railways have placed a contract with P. and W. MacLellan, Ltd., Glasgow, for steel bridge-work to the value of £1,666 f.o.b. Glasgow, Hull, Middlesbrough, or Newport.

The Associated Equipment Co., Ltd., Southall, Middlesex, have received the following two orders:—60 "Regent" double-deck 'buses for the Birmingham Corporation, and 20 'buses, two of which will be fitted with heavy-oil engines, for the Municipality of Athens.

The London General Omnibus Co. have ordered from Commer Cars, Ltd., Luton, Bedfordshire, six "Invader" 6 TK type chassis.

The Staveley Coal and Iron Co., Ltd., and Stanton Ironworks, Ltd., have secured contracts for iron pipes from the Crown Agents for the Colonies.

The following contracts have been placed by the Admiralty: Steel rods, discs, sheets, and bars, Hadfields, Ltd., Sheffield; the Rotherham Forge and Rolling Mills, Ltd.; Swift, Levick and Co., Ltd., Sheffield; Andrew's Toledo, Sheffield; and J. Beardshaw and Sons, Sheffield; electro-plated wire, Mappin and Webb; Walker and Hall; Gladwin's, Ltd., and Viner's, Ltd., Sheffield; clamps and vices, Charles Neill and Co., Ltd.; Easterbrook, Allcard and Co., and C. and J. Hampton, all of Sheffield.

Crossley Motors, Ltd., Manchester, have received an order from Portsmouth Town Council for six double-deck 'buses, equipped with heavy-oil engines, at a cost of £1,900 each. Manchester Corporation Transport Committee also have decided to purchase four more Crossley 'buses fitted with heavy-oil engines.

John I. Thornycroft and Co., Ltd., Basingstoke, Hants., have received an order from the Southern Railway for one 6-ton tipping wagon, and three 2-ton forward-control lorries.

The Great Western Railway Co. has placed the following contracts:—62,000 steel sleepers—Guest, Keen and Nettlefolds, Ltd., Birmingham; the United Steel Companies, Ltd. (Workington Iron and Steel branch); Dorman, Long and Co., Ltd., Middlesbrough; and the Ebbw Vale Steel, Iron, and Coal Co., Ltd., Ebbw Vale, Monmouthshire; the erection of a new carriage shed at Cardiff, at a cost of £20,000—Bernard Hinds and Co., Morriston, Swansea.

The following contracts have been placed by the Southern Railway:—32,000 tons of steel rails, divided between United Steel Companies, Ltd. (Workington Iron and Steel Co. branch), British (Guest, Keen, Baldwin's) Iron and Steel Co., Ltd., Cardiff, and the Cargo Fleet Iron Co., Ltd., Middlesbrough; 5,000 tons of steel sleepers—United Steel Companies, Ltd. (Workington Iron and Steel branch).

Sir William Arrol and Co., Ltd., Glasgow, has received orders from the L.N.E. Railway Co. for four coaling appliances for their Harbour Terrace coal staith at West Hartlepool, and from the Madras and Southern Mahratta Railway Co. for two 35-ton overhead electric travelling cranes, one 15-ton overhead electric travelling crane, ten 4-ton monorail cranes, and one 5-ton crane conversion.

Messrs. Richard Dunston, Ltd., Thorne, have received an order for two specially designed steel lighters of heavy construction, for service at Hull.

The L.N.E. Railway Co. have placed the following contracts: with the Buda Co. (England), Wembley, Middlesex, for 12 petrol-driven permanent-way motor trollies for use in the North of England; with Messrs. D. Wickham and Co., Ware, Herts., for six trollies, four for use in the North and two for use in the South and Midlands; with Holloway Brothers (London), Ltd., Newcastle-on-Tyne, for construction work in connection with the East quay at the Royal Dock, Grimsby; and orders for 40,000 tons of British steel rails with Messrs. Dorman Long and Co., Ltd., Middlesbrough; the Cargo Fleet Iron Co., Ltd., Middlesbrough; Messrs. Pease and Partners, Ltd., Saltburn; Messrs. S. Fox and Co., Ltd., Sheffield; Messrs. D. Colville and Son, Ltd., Glasgow; and the Steel Co., Ltd., of Scotland.

Murrell's Wharf, Ltd., London, S.E., have placed an order with Fodens, Ltd., Sandbach, Cheshire, for four "speed-six" 6-ton and four "speed-twelve" six-wheeled steam wagons. All are fitted with three-way tipping bodies and pneumatic tyres. The order also includes four 6-ton side-tip trailers.

Ruston and Hornsby, Ltd., of Lincoln, have received an order for a six-cylinder vertical airless-injection cold-starting oil engine of 600 b.h.p. This engine, when installed in Elgin power-station, will, it is believed, be the largest in Scotland. There are already three Ruston engines installed in the power station, and this new addition will bring them to a total of 1,000 b.h.p.

John Thompson Water Tube Boilers, Ltd., Wolverhampton, have received the following two orders: A complete boiler unit for Woolwich Arsenal, from the War Office; and two complete boiler units for the London County Hall, from the London County Council.

Lithgows, Ltd., of Port Glasgow, have received an order for a high-class passenger vessel with accommodation for 200 persons, for Yugoslav owners.

Among orders recently received by the Albion Motor Co., Ltd., Glasgow, are the following: Two 6-ton and six 2-ton lorries for the London County Council; eight "Valkyrie" type chassis for the London, Midland and Scottish Railway (Northern Counties Committee), Belfast, and eleven for W. Alexander and Sons, Ltd.; thirty-five 3-ton chassis for the Anglo-Persian Oil Co., Ltd. (for use by the British Petroleum Co.); four 30/35-cwt. chassis for Derby Corporation; and a repeat order for 3-ton vehicles for J. Lyons and Co., Ltd.

The New International Association for Testing Materials.

The first Congress of the above Association will be held from September 6 to 12, 1931, in the Buildings ot the Swiss Federal Polytechnicum, Zurich, under the Presidency of Professor A. Mesuager. A very comprehensive list of subjects has been chosen for discussion, which has been divided to form group subjects under the respective headings: Metals; Non-metallic Inorganic Materials; Organic Materials; and Questions of General Importance. Group A will include a consideration of the testing of cast iron; strength of metals at high temperatures; fatigue; notch-bar impact test; and the progress of metallography. At these discussions Dr. W. Rosenhain will be chairman.

The subjects to be considered in Group B include natural stone; Portland cements, cements with hydraulic ingredients, such as trass, pozzolane, santorin, earth, and blast-furnace slag; aluminous cements; concrete; influence of chemical agents on cements and concrete; and reinforced concrete. Under this group the chair will be taken by Professor M. Roš.

In Group C will be included the ageing of organic substances; timber; asphalt and bitumen; and fuel. The chairman in this instance will be Professor J. O. Roos.

The subjects for discussion in Group D include fundamental and test relations between elasticity and plasticity, toughness, and brittleness; determination of grain size in loose materials; and the calibration and accuracy of testing machines. The chairman in this group will be Professor W. von Möllendorf.

Members affiliated to the British Branch are advised to send in applications for advance proofs of subject matter to be discussed at this Congress, and also for any information regarding the general programme to the Secretary-Treasurer of the New International Association for Testing Materials, 28, Victoria Street, London, S.W. 1.

Catalogues and Other Publications.

The main feature of the *Nickel Bulletin* for March, 1931, is an illustrated article entitled "The Use of Nickel in Chemical Plant." This deals with the properties of nickel (resistance to corrosion, etc.), and quotes some typical applications both in the chemical and foodstuffs (dairy, etc.) industries. Other articles in this issue are: "The Manufacture of Nickel-silver Watch Cases" and "Centrifuges for Cleansing Oil," while reference is made to nickel cast iron in engines built by Messrs. W. Sisson and Co., Ltd., Gloucester. Abstracts and references cover almost every sphere of the nickel industry.

Opening with a short commentary on the development of pipe-line work, with special reference to welding, the March issue of the *Welder* contains a number of informative and well-illustrated articles. These include: "The Design of Welded Steel Structures," by H. A. McCreadie, C.E., Part V.; "The Tallest Welded Building," by Orville Adams; "The Electric Arc Welding of Aluminium," by W. N. Dunlap; "The Welding of Mild Steel with Cresta Electrodes for Forging Purposes," by William Bennett; and "Electric Arc Welding on Ships." Other subjects dealt with are: "Worn Railway Crossings," "Welded Tanks for a Distillery," and "An All-welded Steel Barge." The illustrations include three photographs of the stand of Murex Welding Processes, Ltd., at the British Industries Fair, Birmingham.

The British Aluminium Co. are to be congratulated on the manner in which they have chosen to publish information on aluminium. "Aluminium Broadcast" is a journal which should be of considerable interest to the ordinary metallurgist, for it is issued in typewritten form with the matter on one side of the page only, being, therefore, admirably suitable for filing purposes. In addition to a brief editorial, No. 6, vol. iii, of this journal contains abstracts and reviews of a number of interesting papers and articles. These include: "Aluminium Alloys for Forging and Rolling," "The Use of Aluminium in the Oil Industry," "The Electrical Conductivity and Tensile Properties of Light Magnesium-aluminium Alloys as Affected by Atmospheric Exposure," "Observations on the Riveting of Aluminium and its Alloys," and many others.

IRON AND STEEL REPORT.

The full extent of the depression in the iron and steel industries during the past year may be gauged from the latest returns available at the time of writing, issued by the National Federation of Iron and Steel Manufacturers. At the end of February last the number of blast furnaces in operation was 81, a net decline of two since the beginning of the month, four furnaces having ceased operations and two having commenced. The production of pig iron amounted to 320,200 tons, compared with 337,200 tons in January and 607,000 tons in February, 1930. The February output of steel ingots and castings amounted to 486,400 tons, compared with 402,200 tons in January, and 776,400 tons in February, 1930. The apparent increase in February of this year compared with the previous month was largely due to the fact that the January output of steel was affected by New Year holidays in certain districts. On the whole, however, it is not improbable that the March returns of the National Federation will register some degree of improvement both in foundry iron and steel, for in one or two areas during the past month a measure of seasonal expansion of the demand has been reported.

In the case of pig iron, the weak spot so far as the Lancashire markets are concerned is the textile machinery industry. The demand from this branch is appreciably below what it should be under conditions of normal industrial activity, and at the present time there is little indication of improvement. Machine tool makers, and also certain of the general foundries in the Lancashire district, have latterly been somewhat better situated, and pig-iron deliveries during the month have been on a slightly bigger scale. In the Midland region the movement of pig iron has only been moderate generally, with indications of broadening inquiry on the North-East Coast. In Scotland conditions remain quiet, and supplies are readily obtainable from the seven furnaces in blast.

Not much in the way of price development has occurred in the foundry iron markets since last report. Midland producers—Derbyshire, Staffordshire, and Northamptonshire—have seen no reason to revise the zone rates previously ruling, and except under very keen pressure from makers in outside districts, are unlikely for the present to bring prices down farther. On this point, it is interesting to note that in their attempts to regain part of the market in certain areas, notably Lancashire, North-East Coast makers have cut rates for Cleveland iron to the equivalent of Midland zone prices, but the former have been for so long out of the market in Lancashire that considerable difficulty is being, and will continue to be, experienced in the fight for orders.

In the finished iron section, producers of the best quality bars continue to be moderately well engaged, but the makers of crown and lower quality bars, especially those for the nut and bolt trades, are passing through a very difficult time, and productive operations are on a much reduced scale.

The steel market has been quite steady during the period under review, so far as the controlled materials are concerned. In other departments, however, the tendency is easy, and notably in small re-rolled bars prices are much lower than before. Sellers of high-carbon and alloy steels have reported a fair weight of business in the aggregate, without, however, much appreciable expansion in the rate at which heavy steel is going into consumption among constructional engineers, locomotive builders, and boiler makers, with complaints also heard from the leading shipbuilding centres. As has been indicated, however, signs of slight improvement are not wanting, and rollers are hopeful that bigger tonnages will be taken during the next month or two. Among constructional engineers, in particular, a number of important jobs are known to be held up for various reasons, and there are expectations that some at least of these will shortly be released. Moreover, there is more than a possibility of a start being made on new bridgework by railways and local authorities.

Oil Fuel from Coal.

CONSIDERABLE attention is, at the moment, being focussed on research work in connection with the production of fuel oil from coal. This work has been going on for twelve or eighteen months, and many interesting and surprising results have been obtained. The very fact that it is possible to produce any sort of oil from coal is surprising to many people, but tests have shown that oil so produced gives almost the same results as natural oil. The Admiralty have recently been conducting experiments in this direction, both in the laboratory and in conjunction with a number of low-temperature carbonisation works in this country. As much as 120 gals. of fuel oil has been obtained from one ton of coal, and samples of different qualities have been found to be as good as natural oil in some of the most important factors.

It must not be imagined that ordinary bituminous or household coal is used for oil production. There are in the United Kingdom many seams of material which are practically useless as domestic fuel, but which will yield large quantities of good oils when treated in a certain way. The results obtained, therefore, are to a great extent due to choice of materials.

Many people may not realise the significance of these new developments, but they are of considerable importance and open up possibilities hitherto undreamt-of.

Great Britain is at present dependent on outside supplies of oil, which is imported in very large quantities every year. Her position, therefore, would be somewhat awkward in the event of this supply being cut off. It now appears that if some of the millions which are spent annually on imported oil were expended on oil production in this country, not only would a reserve supply be created independent of outside sources, but also the present depression in the coal industry would be minimised to a great extent. Japan has already set an example in this respect, for a shale-oil industry is being developed at Fushun, in South Manchuria, some 4,000 tons of shale being distilled daily. The Japanese Government has undertaken to purchase the total output at the current price of crude oil. This, of course, entails severe loss to the South Manchurian Railway, who own the shale deposits and plant, but the Government has also undertaken to make good the loss and write it off as a National Defence Fund.

Great Britain is in a position to follow this example, but in her case the cost would be almost negligible. It remains to be seen whether advantage will be taken of these possibilities.

Aluminium's Rapid Development.

In spite of present industrial conditions, there seems to be an ever-widening field for the use of aluminium and its alloys in industry. This is best illustrated in the case of the transport and electrical industries, both of which absorb a considerable proportion of the aluminium output of this country. Aluminium alloy parts, notably pistons, are being increasingly used in all branches of the automobile industry, and as there seem to be prospects of enormous developments in that industry, the output of aluminium should not suffer in this direction. Not only have there been developments in actual output, but a remarkable technical advance has been made in regard to the manufacture of large aluminium castings. Aluminium alloy pistons, weighing over 800 lb. per casting, are being adopted for use in Diesel engines. In the electrical industry there is a large demand for aluminium conductors for overhead lines, and for castings, sheets, and sections for switchgear and other apparatus. In his address at the Annual Meeting of the British Aluminium Co., in London, on March 31, Lt.-Colonel R. W. Cooper, O.B.E., M.C. (chairman of the company), spoke of these developments and of the general state of the aluminium industry, and also referred to the developments at the Lochaber Works of the company. These, when finished, will, it is understood, be by far the largest hydro-electrical installation in this country, and, as the company has already increased its reserve of bauxite ore to a very large quantity, considerable advance should be made in the use, output, and qualities of aluminium and its alloys.

MARKET PRICES

ALUMINIUM.

99% Purity		£85	0	0

ANTIMONY.

English		£36	0	0
Chinese		25	0	0
Crude		22	0	0

BRASS.

Solid Drawn Tubes	lb.	9¾d.
Brazed Tubes	lb.	11¾d.
Rods Drawn	,,	9¼d.
Wire	,,	8¾d.
*Extruded Brass Bars	,,	5d.

COPPER.

Standard Cash		£42	11	3
Electrolytic		45	10	0
Best Selected		44	5	0
Tough		43	15	0
Sheets		77	0	0
Wire Bars		47	12	6
Ingot Bars		47	12	6
Solid Drawn Tubes	lb.			11d.
Brazed Tubes	,,			11d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	1	11¼
‡Ferro Tungsten	,,	0	1	8¼
§ Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2-4% Carbon, scale 11/- per unit	ton	28	0	0
4-6% Carbon, scale 7/- per unit	,,	21	17	6
6-8% Carbon, scale 7/- per unit	,,	21	0	0
8-10% Carbon, scale 7/- per unit	,,	20	15	0
§ Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit	,,	31	0	0
Guar. max. 1% Carbon, scale 13/6 per unit	,,	34	2	6
§ Guar. max. 0.7% Carbon, scale 15/- per unit	,,	37	17	6
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	,,	0	2	7
§ Ferro-Vanadium 25-50%	,,	0	12	8
§ Spiegel, 18-20%	ton	6	17	6
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	5	17	6
20/30% basis 25%, scale 3/- per unit	,,	7	0	0
45/50% basis 45%, scale 5/- per unit	,,	10	2	6
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	25	6	0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	14	0	0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
§ Ferro Phosphorus, 20-25%	ton	15	10	0

FUELS.

Foundry Coke—							
S. Wales Export	£1	2	0 to	£1	16	6
Sheffield Export	0	14	0 to	0	15	0
Durham Export	1	6	0 to	1	8	0
Furnace Coke—						
Sheffield Export	0	14	0 to	0	15	0
S. Wales ,,	0	16	6 to	0	17	6
Durham	0	13	6 to	0	14	0

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£59	10	0
*Commercial Ingots		50	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

LEAD.

Soft Foreign	£12	5	0
English	13	15	0

MANUFACTURED IRON.

Scotland—			
Crown Bars	£10	5	0
N.E. Coast—			
Rivets	11	10	0
Best Bars	11	5	0
Common Bars	10	15	0
Lancashire—			
Crown Bars	10	5	0
Hoops	13	0	0
Midlands—			
Crown Bars	10	7	6
Marked Bars	12	10	0
Unmarked Bars		—	
Nut and Bolt Bars	9	0	0
Gas Strip	10	17	6
S. Yorks.—			
Best Bars	11	0	0
Hoops	12	0	0

PHOSPHOR BRONZE.

*Bars, Tank brand, 1 in. dia. and upwards	lb.	11d.
*Cored Bars	,,	1/1
†Strip	,,	1/0¾
†Sheet to 10 W.G.	,,	1/0¾
†Wire	,,	1/1
†Rods	,,	1/0¾
†Tubes	,,	1/5
†Castings	,,	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	12	0
Foundry No. 1	3	16	0
,, No. 3	3	13	6
N.E. Coast—			
Hematite No. 1	3	7	6
Foundry No. 1	3	1	0
,, No. 3	2	18	6
,, No. 4	2	17	6
Cleveland—			
Foundry No. 3	2	18	6
,, No. 4	2	17	6
Silicon Iron	3	1	0
Forge No. 4	2	17	0
N.W. Coast—			
Hematite	4	6	6
Midlands—			
N. Staffs Forge No. 4	3	6	0
,, Foundry No. 3	3	11	0
Northants—			
Forge No. 4	3	2	6
Foundry No. 3	3	7	6
Derbyshire Forge	3	6	0
,, Foundry No. 3	3	11	0
West Coast Hematite	4	4	6
East ,, ,,	4	1	6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6	0	0 to	£7	10	0
Bars, hammered, basis	£17	10	0 ,,	£18	10	0
Blooms	£10	0	0 ,,	£12	0	0
Keg steel	£32	0	0 ,,	£33	0	0
Faggot steel	£20	0	0 ,,	£24	0	0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£37	0	0
,, Braziery	34	0	0
,, Wire		—	
Brass	26	0	0
Gun Metal	35	0	0
Zinc	6	0	0
Aluminium Cuttings	50	0	0
Lead	10	0	0
Heavy Steel—			
S. Wales	2	7	6
Scotland	2	5	0
Cleveland	2	5	0
Cast Iron—			
Lancashire	2	5	0
S. Wales £2 8 0 to	2	10	0
Cleveland £2 7 6 to	2	9	0
Steel Turnings—			
Cleveland	1	10	0
Lancashire	1	0	0
Cast Iron Borings—			
Cleveland	1	5	0
Scotland	1	13	6

SPELTER.

G.O.B. Official		—	
Hard	£9	7	6
English	12	5	0
India	11	0	0
Re-melted	10	15	0

STEEL.

Ship, Bridge, and Tank Plates—			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	10	10	0
,, ,, (Marine) ,,	10	10	0
,, ,, (Land), N.E. Coast	10	0	0
,, ,, (Marine) ,,	10	10	0
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails	8	15	0
Sheffield—			
Siemens Acid Billets	9	10	0
Hard Basic .... £8 12 6 to	9	2	6
Medium Basic .. £7 2 6 to	7	12	6
Soft Base	6	5	0
Hoops	10	5	0
Manchester—			
Hoops	9	15	0
Scotland, Sheets 20 W.G.	9	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten.	lb.	2/9
Extras		
Round and Squares, ½ in. to ¾ in.	,,	3d.
Under ¼ in. to 3/16 in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅜ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£113	17	6
English	115	0	0
Australian	116	10	0
Eastern	119	10	0
Tin Plates I.C. 20 × 14	box		15/6
Block Tin Cash	£119	5	0

ZINC.

English Sheets	£21	0	0
Rods	23	0	0
Battery Plates	15	15	0

* McKechnie Brothers, Ltd., quoted April 8. † C. Clifford & Son, Ltd., quoted April 8. ‡Murex Limited, quoted April 8.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices:—Wrought Iron Bars, £10 5s. 0d.; Mild Steel Bars, £7 0s. 0d.; Wrought Iron Hoops, £12; Best Special Steel Baling Hoops, £8 10s. 0d. to £8 15s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £8 0s. 0d. to £8 5s. 0d; C. R. & C. A. Steel Hoops, £11 10s. 0d. to £12 0s. 0d; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted April 8. § Prices quoted April 8, ex warehouse.

Vol. 3—No. 13. NOVEMBER, 1930. Price 2/-

METALLURGIA

THE BRITISH JOURNAL OF METALS.

Characteristics of Nickel: I

The use of Nickel has increasec
Ferro

NICKEL is a metal which has come into widespread use within comparatively recent years. It is almost white in colour, approaching rather closely to silver white, is highly resistant to corrosion and oxidation, is non-toxic, and has very good mechanical properties, which, of course, vary to some extent according to the treatment to which the metal has been subjected. It is malleable and ductile, and can be obtained in any of the usual fabricated forms, as well as in the form of castings. It may be welded, brazed, or soldered by any of the well-known methods, and can also be welded to steels and other alloys. Pure nickel is magnetic at ordinary temperatures, but loses its magnetic properties when raised to a temperature of 340° C. It comes under the group of high-melting-point metals, its melting point, according to the most recent determinations, being 1,454.9° C.

Nickel and its alloys have a very wide range of commercial applications. Pure nickel is employed in such industries as the chemical, food, wireless, and electrical industries, but the proportion of the total nickel produced used as pure nickel is small as compared with the quantities used for alloy purposes. It is now extensively employed in the manufacture of alloy steels, non-ferrous alloys such as nickel-copper, nickel-chromium alloys, etc., while it has recently been used for alloying with cast iron. It is also used in the form of anodes, and as salts in the electroplating industry for the production of protective and decorative coatings.

Like nickel, many of its alloys are highly resistant to corrosion and to oxidation at high temperatures. These properties are particularly useful in meeting the severe demands of modern industrial processes.

NICKEL ORES.

Before the discovery in 1865 of the New Caledonian ores by Jules Garnier, and later of the Canadian ores, the most important ores of nickel were "kupfer-nickel" or arsenical nickel, occurring in Germany, France, and Austria; nickel sulphide ores mined in Cornwall, Scotland, and Wales; nickel serpentine (Garnierite) worked in the Russian Urals, Italy, Spain, and America. The pyrrhotite-chalcopyrite ores similar to those of Sudbury, Canada, occurring in Norway, were, prior to the discovery of the New Caledonian ores, the principal supply of the metal. The New Caledonian ore is a hydrated nickel-magnesium silicate, containing on an average 5.4 per cent. nickel, and named "Garnierite" after its discoverer. For many years this proved to be the most important source of the metal, and is still second only in importance to the Canadian ores.

The Sudbury ore is
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the ore is first roasted t
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EXTRACTIO

The Orford Process.

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Its Ores and Methods of Extrac

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ore is chiefly a compound of nickel, copper, iron, and sulphur, as nickeliferous pyrrhotite. The nickel is extracted by various h the Orford and the Mond predominate. For the Orford process asted to reduce the sulphur; it is then smelted with a suitable r-jacketed blast-furnace, or in a reverberatory furnace, yielding ntains the concentrated metals. The matte is treated in a basic ich more sulphur is removed together with the iron, the final ng about 80 per cent. nickel plus copper, 20 per cent. sulphur, iron. For the Mond process a similar matte is obtained by a procedure.

ACTION AND REFINING OF NICKEL.

cess.

is based upon the fact that, in a molten system containing copper sulphide, and sodium sulphide, in general, two liquid the upper carrying the bulk of the sodium and copper sulphides, e bulk of the nickel sulphide. A separation is made.

om the converters is charged into a water-jacketed blast-furnace vert top soda flux from a subsequent operation. The product is allowed to solidify in pots, and a top and bottom are formed tion between the two metals nickel and copper. The bottom, kel, is resmelted with soda flux, and from this operation the top e first smelting of the converter matte. The second bottom— is then passed through a ball mill, and from there to leaching soda and iron are eliminated. The resulting nickel sulphide is lising roast, leached to remove the remaining copper, and a soda ash to remove all fractional remaining impurities. The xide of nickel is ready for the market or reduction to metal in urnace. The metal tapped from this furnace can then be further ically.

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on of nickel by the Mond process is extremely interesting, and ly new departure in metallurgical practice from the principles sly guided it. The process depends on the remarkable property kel of forming a volatile compound with carbon monoxide.

When this gaseous compound (n nickel is deposited in the metalli result of the experiments carried o Mond in collobroration with Dr.

As a result of further expe formed a volatile compound wit that of nickel, and that nickel c by this method.

The matte as received is gro being calcined in long mechanica high temperature. This calcina of the remaining sulphur. The treated with hot sulphuric acid i copper sulphate. The solid resid is washed and dried. The dried the reducers, which are large ve into contact with water-gas at a finely divided nickel. This finel which are similar in constructio volatiliser, meeting an upward st compound—nickel carbonyl—is temperature is maintained at a an excess of carbon monoxide, p in contact with nickel pellets h causes the dissociation of the car carbon monoxide liberated and r the pellets from cementing toget at the bottom and recharged at t only the smaller sizes are rechar a very high purity. The residu produced again goes through th

Not the least remarkable fe ture at which the whole operatio is, therefore, not subjected to th metals from their ores. The ope except the water-gas is introdu

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EXTRACTION AND REFINING OF

The Orford Process.

This process is based upon the fact that, in a molte nickel sulphide, copper sulphide, and sodium sulphide, in layers are formed, the upper carrying the bulk of the sodium and the lower the bulk of the nickel sulphide. A separati

The matte from the converters is charged into a water-j with coke and revert top soda flux from a subsequent ope from this furnace is allowed to solidify in pots, and a top a effecting a separation between the two metals nickel and c containing the nickel, is resmelted with soda flux, and from is returned to the first smelting of the converter matte. nickel sulphide—is then passed through a ball mill, and fr tanks, where the soda and iron are eliminated. The result given one chloridising roast, leached to remove the rema second roast with soda ash to remove all fractional remai resulting black oxide of nickel is ready for the market or the open-hearth furnace. The metal tapped from this furna refined electrolytically.

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G OF NICKEL.

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is extremely interesting, and practice from the principles s on the remarkable property und with carbon monoxide.

When this gaseous compound (nickel carbonyl) is heated it decomposes, and nickel is deposited in the metallic form. The process has been developed as a result of the experiments carried out at the end of the last century by Dr. Ludwig Mond in collobroration with Dr. Carl Langer and Dr. Quincke.

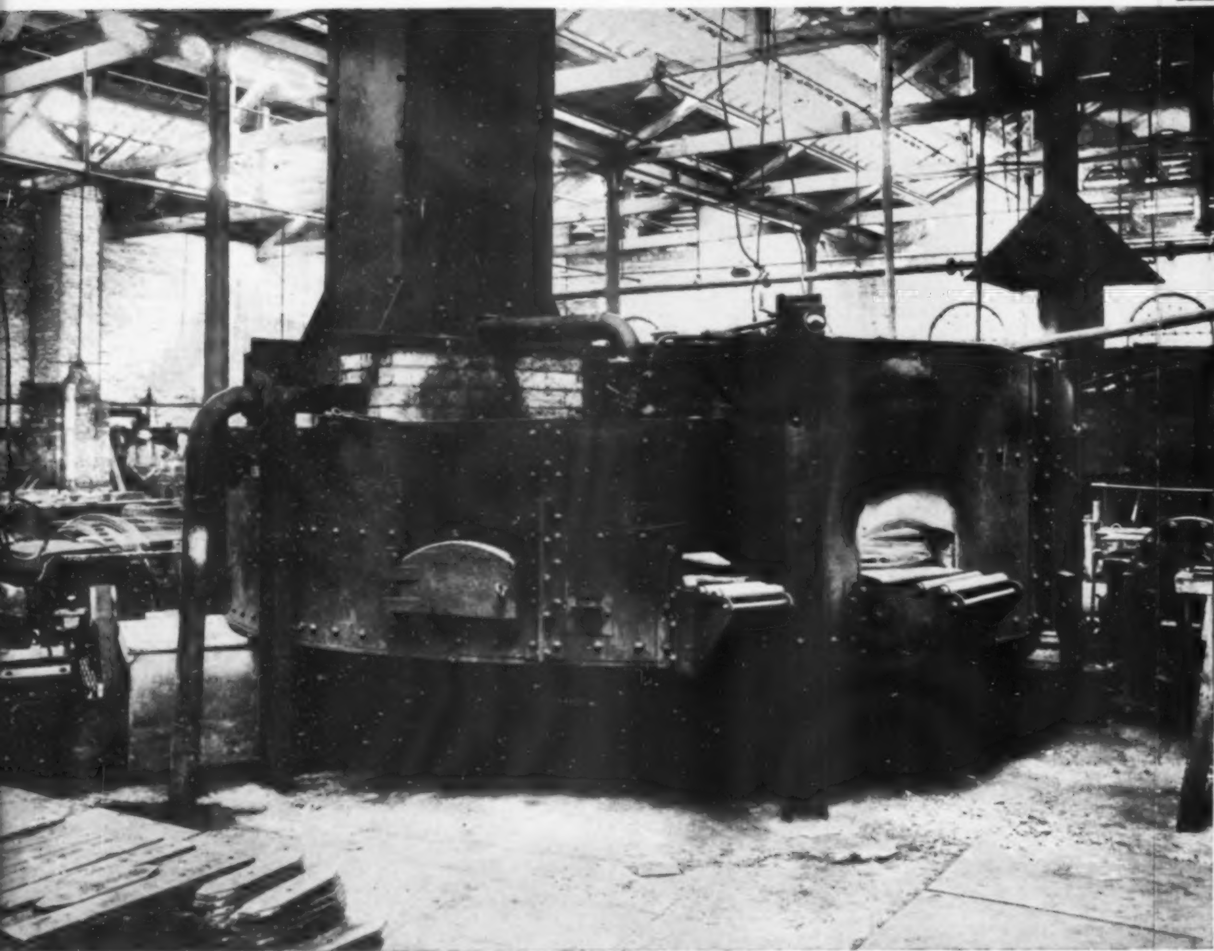
As a result of further experiments it was discovered that no other metal formed a volatile compound with carbon monoxide with a facility approaching that of nickel, and that nickel could, therefore, be separated from other metals by this method.

The matte as received is ground to pass a 60-mesh sieve in ball mills before being calcined in long mechanical furnaces heated by producer gas to a relatively high temperature. This calcination is designed to remove as much as possible of the remaining sulphur. The resulting oxides of nickel and copper are then treated with hot sulphuric acid in order to leach out a large part of the copper as copper sulphate. The solid residue, after filtering off the copper sulphate solution, is washed and dried. The dried copper—extracted matte—is then conveyed to the reducers, which are large vertical gas-tight chambers, in which it is brought into contact with water-gas at a temperature of 330 to 350° C., and reduced to finely divided nickel. This finely divided nickel is transferred to the volatilisers, which are similar in construction to the reducers. The nickel passes down the volatiliser, meeting an upward stream of carbon monoxide gas, and the volatile compound—nickel carbonyl—is formed. The reaction is exothermic, and the temperature is maintained at about 50° C. The volatile nickel carbonyl, with an excess of carbon monoxide, passes over into the decomposers, where it comes in contact with nickel pellets heated to a temperature of about 180° C. This causes the dissociation of the carbonyl, nickel being deposited on the pellets, and carbon monoxide liberated and returned to the volatilisers. In order to prevent the pellets from cementing together they are kept in motion by being drawn off at the bottom and recharged at the top. Those drawn off pass over a screen, and only the smaller sizes are recharged. The pellets obtained by this process are of a very high purity. The residue from the volatilisers is resmelted, and the matte produced again goes through the above cycle of operations.

Not the least remarkable feature of the process is the fact that the temperature at which the whole operation is conducted never exceeds 350° C. The plant is, therefore, not subjected to the high temperatures usually necessary to extract metals from their ores. The operation is a regenerative one, and no new material except the water-gas is introduced into the cycle.

"Metallurgia" Chart, November, 1930.
The Kennedy Press, Ltd., Kennedy House,
Liverpool Road, Manchester.

" MANCHES



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The "MANCHESTER" Rotary Hearth Furnace (Patented) Oil or Gas Fired is eminently suitable for giving continuous outputs of varied classes of work, heated uniformly to temperatures up to and including 1,000° Cent.

The Furnace illustrated is Oil Fired and is operating at 850° Cent., giving a continuous output of 4 in. by ⅜ in. Wagon Spring Plates.

Fuel, Labour and Maintenance Costs are exceedingly low.

There are numerous heat applications where this Furnace shows distinct advantages over the in-and-out type of Furnace, and we shall be pleased to discuss at Works of interested firms any continuous-heat problems.

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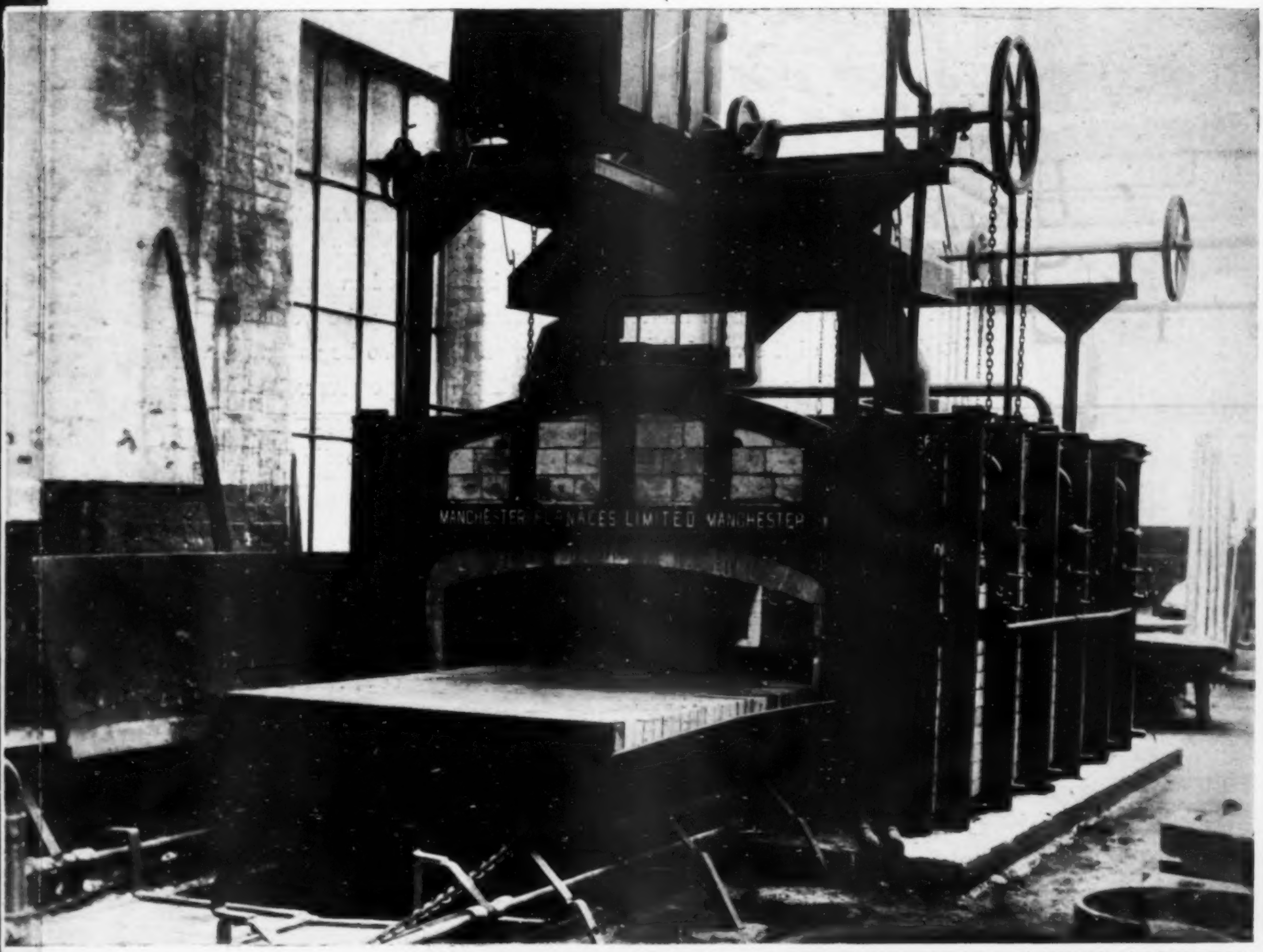

THE "MANCHESTER" BOGIE TYPE OIL OR GAS FIRED FURNACE FOR ANNEALING, NORMALIZING, ETC.,

can be designed to any size to suit Customers' particular requirements.

Suitable for long and heavy work such as Connecting Rods, Shafts, etc., and also Steel Castings, Chain Annealing, and various other classes of work.

Ensures low attendant Labour Costs, as material to be heated is mechanically handled.

All our Furnaces of this type embody recuperative system to ensure maximum utilization of waste heat to obtain highly preheated air supply.

Construction is robust in every detail, and includes highest quality insulating material, thereby ensuring low upkeep and fuel costs.

Fully detailed proposals submitted on request.

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RKS MANCHESTER

Vol. 3.—No. 14. DECEMBER, 1930 Price 2

METALLURGIA

THE BRITISH JOURNAL OF METALS.


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FURNACE
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COPPER WIRE
IRON
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Characteristics

ALTHOUGH nickel had been alloyed with iron as early as 1820 by Faraday, yet it was not until after 1870 that serious consideration was given to the study of alloy steels. The French commenced a series of experiments which culminated in the successful production of a nickel steel by Marbeau at the Montataire works in 1885-1887. In 1889 the French steel works of Schneider et Cie at Le Creusot made armour plate from nickel steel which was far superior to that which had been previously produced. In the same year James Riley gave his classic paper on " The Alloys of Nickel and Steel " before the Iron and Steel Institute, and this, together with the work in France, marks the beginning of the commercial development of nickel steels.

Trials in 1891 definitely established the superiority of nickel steels for armour-plate, and the results immediately became of interest throughout the world. Intensive research was carried out on the properties and treatment of nickel steels by all the leading steel manufacturers, which produced much valuable and useful information, of which engineers were not slow to take advantage.

Thus, nickel steels, whilst their first important application was for armaments, soon were used for structural and automobile engineering, and to-day, as a result of continued research and development, a wide range of compositions is available which cover a very wide variety of uses.

INFLUENCE OF NICKEL ON STEEL.

Nickel and iron are soluble in all proportions at elevated temperatures, and at normal temperature, nickel is consequently in solid solution in the iron phase. Depending on the carbon and nickel content, nickel steels, after slow cooling, may have pearlitic, martensitic, or austenitic structure.

In the pearlitic range the addition of each 1% of nickel up to about 8% to steel in the annealed condition, results in an increase of the elastic limit and maximum stress of about 2 tons per sq. in., an increase in the reduction of area and a slight decrease in the elongation. It is, however, in the heat-treated condition that the effect of nickel is most noticeable, as the strength and hardness are increased without any loss in the ductility as compared to a carbon steel.

Nickel also increases the toughness of a steel, which can be ascertained from the higher impact values which are obtained with the increased strength.

Nickel tends to retard grain growth at elevated temperatures, thus allowing, for instance, more latitude in the casehardening operation than is permissible with a carbon steel. On slow cooling it has a tendency to maintain fine grain structure, which is associated with nickel steels.

Nickel steels used for general purposes contain nickel with a range of 1 to 6%, and are associated with carbon varying from 0.1 to 0.5%.

CASEHARDENING NICKEL STEELS.

For those components which require surface hardness to resist abrasion, and at the same time must possess considerable toughness to resist fracture under shock, special steels are required. These steels in their normal condition are tough, and by the process known as casehardening a hard case is produced on the surface, whilst at the same time the original toughness of the steel is retained in the core. Casehardening consists essentially of carburising the component—*i.e.*, introducing extra carbon into the surface by heating for a given time in contact with a carburising material at a temperature in the neighbourhood of 900° C. In the case of plain carbon casehardening steels, this results in a large grain size, which is conducive to brittleness, with the result that in the subsequent heat-treatment two operations are necessary :—

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cs and Qualities of Nickel Steels.

A refining treatment, in which the component is heated up to about 900° C. and d so as to produce a fine grain in the core ; and (2) a second treatment, in which ponent is quenched from about 760° C., which has the effect of both refining and g the case.

effect of nickel in the nickel casehardening steels is, in the first place, to enable trength to be obtained in the core, whilst retaining a high value of toughness, and produce greater uniformity of results. It allows a slower rate of cooling to be d, enabling oil instead of water for quenching, and this reduces to a minimum the listortion and cracking. Also, grinding cracks are avoided, since the case is in a e of stress owing to the oil quench, and also because nickel has the effect of both g the formation of free cementite and producing a less abrupt transition from to the core.

urther important advantage conferred by the nickel is that owing to its restraining e on grain growth at elevated temperatures, the refining heat-treatment can be ed—*i.e.*, only a single quench is necessary, which still retains a tough fibrous core.

carbon content of casehardening steels is usually low, not exceeding 0.2%, and about 0.15%, but with the introduction of nickel the carbon content can, with ge, be lower, because of the hardening effect of the nickel. Thus, the B.S. Speci- for nickel casehardening steels are :—

Carbon.—Not more than 0·15%.
Silicon.—Not more than 0·30%.
Manganese.—Between 0·20 and 0·60%.
Sulphur.—Not more than 0·05%.
Nickel.—2·5% to 3·5% (for 3% nickel steel), and 4·5% to 6·0% (for 5% nickel steel).
Chromium.—Not more than 0·30%.

AVERAGE PHYSICAL PROPERTIES.

3% Nickel Casehardening Steel.

Treatment.	Maximum Stress, Tons/Sq. In.	Yield Point, Tons/Sq. In.	Elongation, % on 2 in.	Reduction of Area, %.	Izod Impact, Ft.-Lb.	Brinell Hardness No.
r oil quench, from and again from	36·6	24·4	37·0	67·8	94, 90, 90	153
r single oil quench, 30° C.	35·5	23·9	35·0	63·7	90, 90, 88	153

5% Nickel Case-Hardening Steel.

Treatment.	Maximum Stress, Tons/Sq. In.	Yield Point, Tons/Sq. In.	Elongation, % on 2 in.	Reduction of Area, %.	Izod Impact, Ft.-Lb.	Brinell Hardness No.
....	37·6	24·8	21	32	55	159
d at 860° C.	40·4	27·6	26	44·8	73	179
r treatment, car- at 900° C., water d at 850° C., and t 750° C.	75·2	50·0	17	56	38·5	340
nch in oil at 780° C.	62·8	52·0	13·5	40·8	39	277

STRUCTU

The nickel structural steels are of high fatigue strength combined average tests obtained from typic

AVERAGE TESTS

Treatment.	Maximu Stress Tons/S In.
As rolled	44
Normalised at 830° C.	45
Oil hardened at 820° C. and tempered in oil at—	
560° C.	54·28
600° C.	53
620° C.	50·88
640° C.	47·4

Suitable for large gears and other parts great toughness an

Treatment.	Maximu Stress Tons/S In.
As rolled	47·2
Normalised at 850° C.	52·4
Oil hardened at 830° C. and tempered at—	
260° C. quenched in oil	99·5
540° C. ,, ,,	60·8
560° C. ,, ,,	58·4
580° C. ,, ,,	55·8
615° C. ,, ,,	50·8

HIG

The high-nickel steels having particularly for gas engine valv extremely tough and dense, and

—
25 to 28% nickel (0·3 to 0·5% carbo
30 to 35% nickel (average) ....

These steels do not respond machining, after which their phy nickel steels giving an average of in 2 in., and a reduction of area

Characteristics and Qualities of

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Sulphur.—Not more than 0·05%.
Nickel.—2·5% to 3·5% (for 3% nickel steel), and 4·5% to 6·0% (for 5% nickel ste
Chromium.—Not more than 0·30%.

AVERAGE PHYSICAL PROPERTIES.

3% Nickel Casehardening Steel.

Treatment.	Maximum Stress, Tons/Sq. In.	Yield Point, Tons/Sq. In.	Elongation, %, on 2 in.	Reduction of Area, %.	Izod Impact, Ft.-Lb.	B Ha
Core after oil quench, from 850° C. and again from 760° C.	36·6	24·4	37·0	67·8	94, 90, 90	
Core after single oil quench, from 760° C.	35·5	23·9	35·0	63·7	90, 90, 88	

5% Nickel Case-Hardening Steel.

Treatment.	Maximum Stress, Tons/Sq. In.	Yield Point, Tons/Sq. In.	Elongation, % on 2 in.	Reduction of Area, %.	Izod Impact, Ft.-Lb.	B Ha
As rolled	37·6	24·8	21	32	55	
Normalised at 860° C.	40·4	27·6	26	44·8	73	
Core after treatment, carburised at 900° C., water quenched at 850° C., and again at 750° C.	75·2	50·0	17	56	38·5	
Single quench in oil at 780° C.	62·8	52·0	13·5	40·8	39	

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STRUCTURAL NICKEL STEELS.

The nickel structural steels are very widely used, because of their well-known advantages of high fatigue strength combined with toughness. In the following tables are given some average tests obtained from typical 3% and 5% nickel steels :—

AVERAGE TESTS FOR STRUCTURAL NICKEL STEEL.

3% Nickel Steel.

Treatment.	Maximum Stress, Tons/Sq. In.	Yield Point, Tons/Sq. In.	Elongation, % on 2 in.	Reduction of Area, %.	Izod Impact, Ft.-Lb.	Brinell Hardness No.
As rolled	44	26	23·5	39·2	34	196
Normalised at 830° C.	45	28·64	28	52	46	196
Oil hardened at 820° C. and tempered in oil at—						
560° C.	54·28	43·2	23	53·6	60	241
600° C.	53	41·2	22·5	54·8	78	235
620° C.	50·88	39·8	26	59·2	79	228
640° C.	47·4	35·6	28·5	62·6	85	207

5% Nickel Steel.

Suitable for large gears and other parts of heavy bulk permitting hardening and tempering, requiring great toughness and strength and high resistance to shock.

Treatment.	Maximum Stress, Tons/Sq. In.	Yield Point, Tons/Sq. In.	Elongation, % on 2 in.	Reduction of Area, %.	Izod Impact, Ft.-Lb.	Brinell Hardness No.
As rolled	47·2	32·0	14·0	21·6	22	207
Normalised at 850° C.	52·4	36·4	16·0	27·6	38	228
Oil hardened at 830° C. and tempered at—						
260° C. quenched in oil	99·5	79·25	14·0	50·4	15	444
540° C. ,, ,,	60·8	53·60	21·0	54·8	60	269
560° C. ,, ,,	58·4	51·0	23·0	57·2	71	262
580° C. ,, ,,	55·8	48·8	24·0	60·4	72	248
615° C. ,, ,,	50·8	41·4	27·0	61·5	85	223

HIGH-NICKEL STEELS.

The high-nickel steels having a nickel content between 25% and 35% are used more particularly for gas engine valves and spindles, ignition, and boiler tubes. They are extremely tough and dense, and have high physical properties as follows :—

—	Tensile Strength, Tons/Sq. In.	Elastic Limit, Tons/Sq. In.	Elongation, % in 2 in.	Reduction in Area, %.
25 to 28% nickel (0·3 to 0·5% carbon)	37 to 41	16 to 22	30 to 35	50 to 60
30 to 35% nickel (average)	42	22	40	58

These steels do not respond to heat-treatment, but may be annealed to facilitate machining, after which their physical properties are modified somewhat, the 30% to 35% nickel steels giving an average of 37 tons per sq. in. tensile strength, an elongation of 30% in 2 in., and a reduction of area of 40%.

"Metallurgia" Chart, December, 1930.
The Kennedy Press, Ltd., Kennedy House,
Liverpool Road, Manchester.

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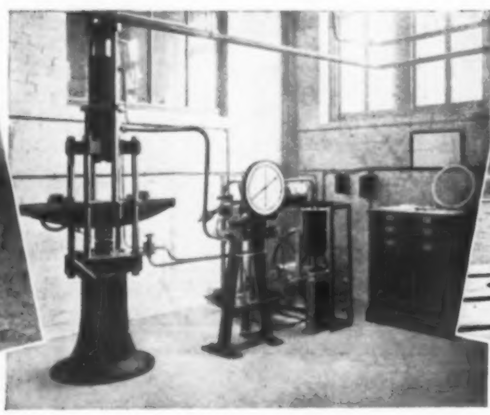
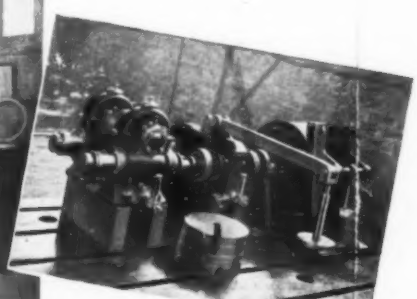
in design
in materials
in manufacturing methods.





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Recent exhaustive tests by the largest purchaser of worm-wheel blanks in this country, showed the DBS Special Centrifugal Bronze to have 40% higher tensile strength, 100% higher elongation, greater density and smaller grain size, than any other blank tested. All blanks were the same size and made to conform with the same specified analysis.

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ears of intensive research and manufacturing experience.

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Every known refinement in control, supervision, manufacturing methods, and raw materials is embodied in the DBS worm gear. Our business as the World's largest gear specialists has been built up on quality of product.

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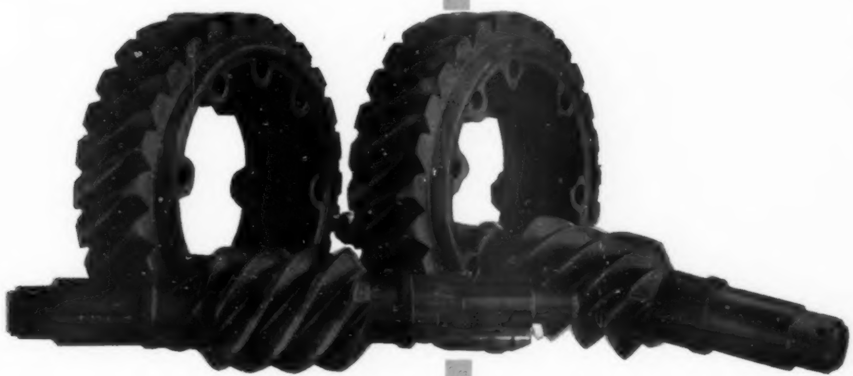

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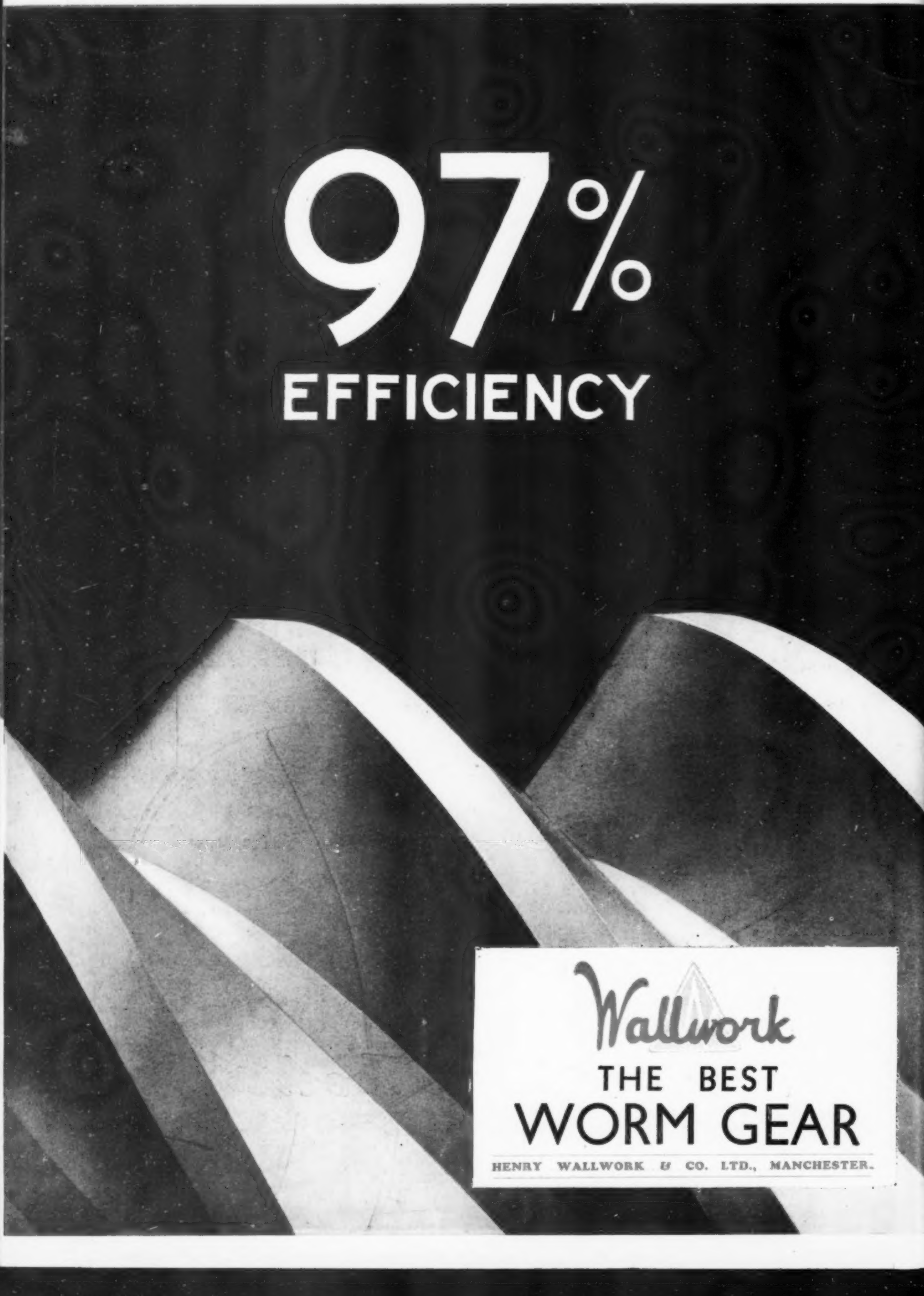
METALLURGIA

THE BRITISH JOURNAL OF METALS.



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EFFICIENCY
Wallwork
THE BEST
WORM GEAR
HENRY WALLWORK & CO. LTD., MANCHESTER.

Chromium, its Ores, M

Metal Compositions to withstand corrosion and heat are

ALTHOUGH discovered as long ago as 1797 by Louis Nicolas Vauquelin, a Frenchman, it is only during comparatively recent years that the value of chromium has been appreciated and its use extended. One of its rarer ores, chromate of lead, $PbCrO_4$, was first investigated by Vauquelin and Macquart in 1789, and in 1797 by Vauquelin, who found that the lead was in combination with an acid, which he recognised as the oxide of a new metal. The chromate of lead or crococite, upon which these investigations were made, is frequently associated with other ores, but no workable deposits are known.

The only important source of chromium is chromium iron ore, or chromite, $FeCr_2O_4$ Rhodesia produces by far the greater amount of chromite, while considerable deposits are worked in India and California ; smaller deposits are, however, successfully worked in many other countries, notably those in Bosnia, Cuba, South Africa, and Japan

The ore chromite is a heavy mineral, and is readily obtained in a concentrated form by gravity methods. In the majority of instances the deposits are found in countries having a plentiful supply of cheap labour, and hand-picking is frequently adopted with the coarser ores.

EXTRACTION OF CHROMIUM.

The metal is obtained by various processes. Thus, Sainte Claire Denville prepared it as a very hard substance of steel-grey colour by strong ignition of chromic oxide and sugar charcoal in a lime crucible, while F. Wohler reduced the sesquioxide by zinc and obtained a shining green powder.

The requirements of modern industry have resulted in the development of three distinct metallurgical processes, the chromium being extracted in forms suitable for steel manufacture, the dyeing and tanning industries, and for special alloys of chromium free from iron, having very low electrical conductivity, and great resistance to corrosion at high temperatures.

The methods employed to conform with these requirements are :—

1. The smelting of chromite to produce ferro-chrome.
2. The manufacture of chromates and bichromates by the chemical treatment of chromite.
3. The production of metallic chromium by chemical extraction of chromic oxide from chromite followed by the reduction of the oxide to metal by the thermit process.

THE PRODUCTION OF FERRO-CHROME.

Theoretically, the reduction takes place according to one of two reactions :—

$$Fe\ Cr_2O_4 + 4\,C = Fe_2Cr + 4\,CO$$

$$9\,(FeCr_2O_4 + 50\,C = [2\,(Fe_3C_3Cr_3C_2)] + 3\,Fe + 36\,CO.$$

These reactions represent two extremes, the first in which carbon-free ferro-chrome is produced in a single operation, while the second produces an alloy containing the maximum percentage of carbon, 10.4%. In practice the first reaction never takes place, and the second is very uncommon, so that ferro-chrome produced by melting chromite has a carbon content which may vary between 4 to 8%, depending to some extent upon the grade of ore used and the method employed. The reduction may be accomplished in shaft furnaces, but it is performed preferably in crucible or electric furnaces. In the crucible process heating is generally provided by a regenerative gas furnace, usually having two chambers for alternate use. Either clay or graphite crucibles may be used ; the former, being cheaper, are generally preferred.

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Methods of Extraction and

at are probably the most important developments resulting from the use of Chromiu

ore and charcoal are generally mixed and bonded with pitch, in order to ensure timate contact between the ore and reducing agent, the approximate ratio of rcoal and pitch used in the production of the alloy being 16—2—1 respectively

development of the electric furnace has facilitated the reduction of the ore by hod, and its use for this purpose has progressed to such an extent that much of the ome now used is produced by means of arc furnaces, single-phase being frequently h a fixed electrode under the hearth and an adjustable electrode at the top. With e of furnace, powdered chromite is mixed with coarse coal and charged into the the charge being kept heaped about the electrode. The molten metal settles at om, and is tapped out at regular intervals. It is worthy of note that these furnaces te little in practice; they may be operated for a long time at low maintenance

smelting an ore containing 40 to 50% of chromic oxide an alloy containing 60 to hromium is produced. The 4 to 6% and the 6 to 8% carbon grades are the result itial smelting. The lower-carbon alloys are made by refining high-carbon ferro-n with an oxidising slag of chromite to remove the carbon. The operation must olled and conducted with great care, otherwise the chromium will oxidise

he production of 6 to 8% carbon alloy, a recovery of 90 to 95% of chromium is . This is due to an excess carbon being permissible and to the charging of fluxing s, which assist in producing a higher carbon alloy, giving a more fluid slag, resulting separation of slag and metal. With 4 to 6% carbon alloy the recovery of chromium tween 70 and 80%. A considerable proportion of the loss is in metallic particles, e retained in the slag, practically all of which can be removed by concentration.

recovery of the chromium, being greater in the higher-carbon grades, affects the he alloys, which are graded according to their carbon contents; the lower the ge of carbon the higher the cost.

THE PRODUCTION OF CHROMIUM.

metal chromium is produced commercially by the thermit process. In this process reaction is produced between chromic oxide and aluminium powder; the raction rmic and conforms to the following equation:—

$$Cr_2O_3 + 2Al = 2Cr + Al_2O_3$$

rder to provide chromic oxide for this purpose, sodium bichromate is reduced hur, the two being associated and subjected to external heat, producing the chromic cording to the equation:—

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thermit reduction of the chromic oxide is made in a furnace lined with magnesite, the reaction with aluminium powder is exothermic, no external heat is necessary. mium metal produced contains some aluminium, but is technically free from nd, if a high grade of chromic oxide is reduced, from other impurities also a metal of 99.5% purity can be made by manipulating the amount of the aluminium

CHARACTERISTI

Chromium is a bluish whit extremely hard crystalline elem hardness of 75. Its specific gra 0.1039, electrical conductivity a Pure chromium melts at 1,520 by the presence of carbon, bei

In melting chromium for siderably because it is highly

Chromium is only attacke Dilute nitric acid causes it to however, rapidly attacked by dioxide; on the other hand, ho is very resistant to corrosion b At a temperature of 1,200° C. i

APPLIC

The most universal applic with iron and steel. Chromium steel was invented. It was use material. Wrought iron was t use of steel alloyed with chromi considerable attention, not so use of steel for such a purpose. alloy; it was not until the dev mercial importance of chromiu one of the few alloys associated w are found in the casehardening as ball-bearing steels. This re steels are defeating corrosion an property was due to Brearley, covered a hardened and polished of stainless iron and steel. The that iron and steel containing scaling which exceeded ordinar in alloy steels for heat-resisting

The application of chromiu progress, particularly in connect open question whether it is not be as a substitute for silver or ni factured and applied to a wide ra are being unfolded almost daily. resisting alloys at high temperat

Chromium is used as an allo connected with nickel, but chro low cost, finds many applicatio shrinkage. It improves the text carbon, but when the chromium to be encountered, as it promote up by additions of silicon or n

ium, its Ores, Methods of Ext

mpositions to withstand corrosion and heat are probably the most important development

Louis Nicolas Vauquelin, a Frenchman, s that the value of chromium has been its rarer ores, chromate of lead, $PbCrO_4$, 1789, and in 1797 by Vauquelin, who , which he recognised as the oxide of a which these investigations were made, rkable deposits are known.

mium iron ore, or chromite, $FeCr_2O_4$. omite, while considerable deposits are are, however, successfully worked in a, South Africa, and Japan.

dily obtained in a concentrated form deposits are found in countries having s frequently adopted with the coarser

ROMIUM.

Thus, Sainte Claire Denville prepared strong ignition of chromic oxide and reduced the sesquioxide by zinc and

d in the development of three distinct ed in forms suitable for steel manu- special alloys of chromium free from reat resistance to corrosion at high

equirements are :—

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emical extraction of chromic oxide f the oxide to metal by the thermit

RO-CHROME.

g to one of two reactions :—

$+ 4\,CO$

$_2)] + 3\,Fe + 36\,CO.$

n which carbon-free ferro-chrome is es an alloy containing the maximum eaction never takes place, and the ed by melting chromite has a carbon to some extent upon the grade of y be accomplished in shaft furnaces, furnaces. In the crucible process rnace, usually having two chambers be used ; the former, being cheaper,

The ore and charcoal are generally mixed and bonded with pitch, in order to more intimate contact between the ore and reducing agent, the approximate ra ore, charcoal and pitch used in the production of the alloy being 16—2—1 respectiv

The development of the electric furnace has facilitated the reduction of the this method, and its use for this purpose has progressed to such an extent that much ferro-chrome now used is produced by means of arc furnaces, single-phase being freq used with a fixed electrode under the hearth and an adjustable electrode at the top. this type of furnace, powdered chromite is mixed with coarse coal and charged int furnace, the charge being kept heaped about the electrode. The molten metal sett the bottom, and is tapped out at regular intervals. It is worthy of note that these fu deteriorate little in practice ; they may be operated for a long time at low mainte cost.

By smelting an ore containing 40 to 50% of chromic oxide an alloy containing 70% of chromium is produced. The 4 to 6% and the 6 to 8% carbon grades are the of the initial smelting. The lower-carbon alloys are made by refining high-carbon chromium with an oxidising slag of chromite to remove the carbon. The operation be controlled and conducted with great care, otherwise the chromium will oxidise

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CHARACTERISTICS AND PROPERTIES OF CHROMIUM.

Chromium is a bluish white metal which holds its silvery lustre indefinitely. It is an extremely hard crystalline element, harder than glass; in its pure form it has a sclerescope hardness of 75. Its specific gravity at 20° C. is 6.92, while it has a specific heat at 0° C. of 0.1039, electrical conductivity at the same temperature of 15 and heat conductivity of 17.2. Pure chromium melts at 1,520° C. and boils at 2,200° C. The melting point is influenced by the presence of carbon, being lowered considerably, but its hardness increases.

In melting chromium for casting purposes, it requires to be superheated very considerably because it is highly viscous for several hundred degrees after it is melted.

Chromium is only attacked slowly by hydrochloric acid, but rapidly on being heated. Dilute nitric acid causes it to dissolve slowly, as also does dilute sulphuric acid; it is, however, rapidly attacked by concentrated sulphuric acid, with the evolution of sulphur dioxide; on the other hand, hot nitric acid does not affect it appreciably. Pure chromium is very resistant to corrosion by air, oxygen, or chlorine, at temperatures up to 300° C. At a temperature of 1,200° C. it oxidises at about the same rate as nickel.

APPLICATIONS OF CHROMIUM.

The most universal application of chromium is as an alloying material, particularly with iron and steel. Chromium steel, for instance, was of some importance before manganese steel was invented. It was used in bridge construction before steel itself was an orthodox material. Wrought iron was the standard material for constructional purposes, and the use of steel alloyed with chromium in the construction of a railway bridge in 1877 focussed considerable attention, not so much because of the use of chromium, but because of the use of steel for such a purpose. At that time, however, chromium did not prosper as an alloy; it was not until the development in the manufacture of motor-cars that the commercial importance of chromium as an alloying material became recognised. To-day it is one of the few alloys associated with steels from the softest range to the hardest. Its products are found in the casehardening range, the medium-hard steels, and the hard steels, such as ball-bearing steels. This remarkable alloy is the basis on which the stainless irons and steels are defeating corrosion and its train of evils. The discovery of this valuable stainless property was due to Brearley, who patented it as an improvement in cutlery; the patent covered a hardened and polished steel containing 9—16% chromium. This was the beginning of stainless iron and steel. The discovery was developed and broadened, and it was found that iron and steel containing chromium within the stainless range had a resistance to scaling which exceeded ordinary steel many times. This opened a new field for chromium in alloy steels for heat-resisting purposes.

The application of chromium as a substitute for silver or nickel has made remarkable progress, particularly in connection with processes involving electro-deposition, but it is an open question whether it is not more valuable as a heat-resisting material than it will ever be as a substitute for silver or nickel. The amount of heat-resisting steel now being manufactured and applied to a wide range of purposes is very considerable, and further applications are being unfolded almost daily. It is worthy of note that the physical properties of heat-resisting alloys at high temperatures are as valuable as their corrosion-resisting properties.

Chromium is used as an alloying element in some cast-iron compositions; it is usually connected with nickel, but chromium itself has certain advantages, and, by reason of its low cost, finds many applications. In general, chromium increases chill, hardness, and shrinkage. It improves the texture, promoting grain refinement, particularly the graphitic carbon, but when the chromium contents exceed 0.4 or 0.5%, machining difficulties are likely to be encountered, as it promotes the formation of carbides; these, however, can be broken up by additions of silicon or nickel.

"Metallurgia" Chart, January, 1931.
The Kennedy Press, Ltd., Kennedy House,
Liverpool Road, Manchester.

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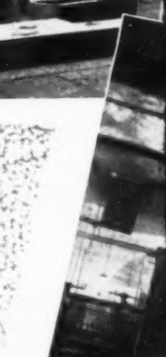
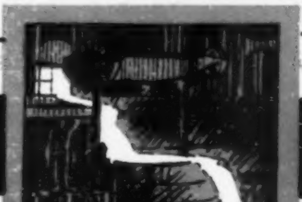




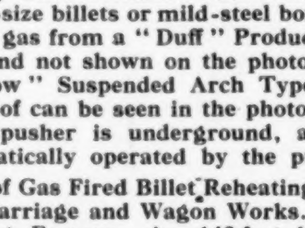
FURNACES for ALL PU
GAS PLANTS for HEATING

WE SHALL be pleased to advise you on the installation of Gas Plants for Power or Industrial Heating Purposes, with a view to securing Economy in the Cost of Produc-tion in your works. We design and build all types of Metallurgical Furnaces, and Specialize in Layouts for New Plants and the Modi-fication or Extension of Existing Plants. This has been our business for the last 40 years.

1. Illustrates a Dowson Improved Open-Hearth Type Gas Plant recently installed for Heating Purposes. This plant is specially designed to produce an exceptionally clean gas, and to deliver same at a constant and regulated pressure to the burners for heating purposes. The gas generator itself is of the open-hearth type in which the fire is in view of the operator all the time the plant is working, and ashing and clinkering can be carried out without any disturbance of the gas supply. The plant has a high thermal efficiency, and the price, including fuel at 38s per ton, wages, water, interest at 7%, depreciation at 10% maintenance, current for booster, oil and other sundries would be 5d. per 1,000 cubic feet, or 3.6d. per therm.
2. Shows a Continuous Furnace having an effective hearth 18 feet long by 14 feet wide. This furnace is suitable for handling large-size billets or mild-steel box sectional material. It is fired with gas from a "Duff" Producer, which is outside the building, and not shown on the photograph. The roof is of the "Bigelow" Suspended Arch Type. The cross-joists carrying the roof can be seen in the photograph. The ram of the hydraulic pusher is underground, and the door-lifting gear is automatically operated by the pusher.
3. Is of a battery of Gas Fired Billet Reheating Furnaces, installed at a Railway Carriage and Wagon Works. And Figure 4 is a Sheet Annealing Furnace, size 142 feet long, capacity about 600 tons per week.
5. This Reheating Furnace is coal fired; it is smokeless in operation, and the fuel consumption is as low as in the most efficient gas-fired type. Our illustration shows an In-and-Out Type. In one case, by installing a furnace of this type, the fuel costs were actually reduced from 9s. 8d. to 2s. per ton of steel heated, these figures including standby charges and the fuel necessary to bring the furnace up to working temperature.

DOWSON & MASO

GAS PLANT COMPANY LIMITED.
ALMA WORKS · · LEVENSHULME, MANCHESTER.



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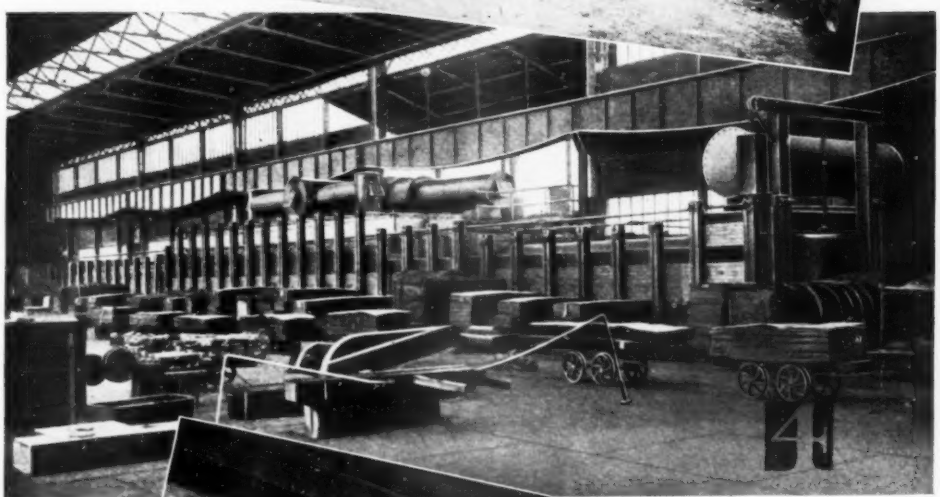

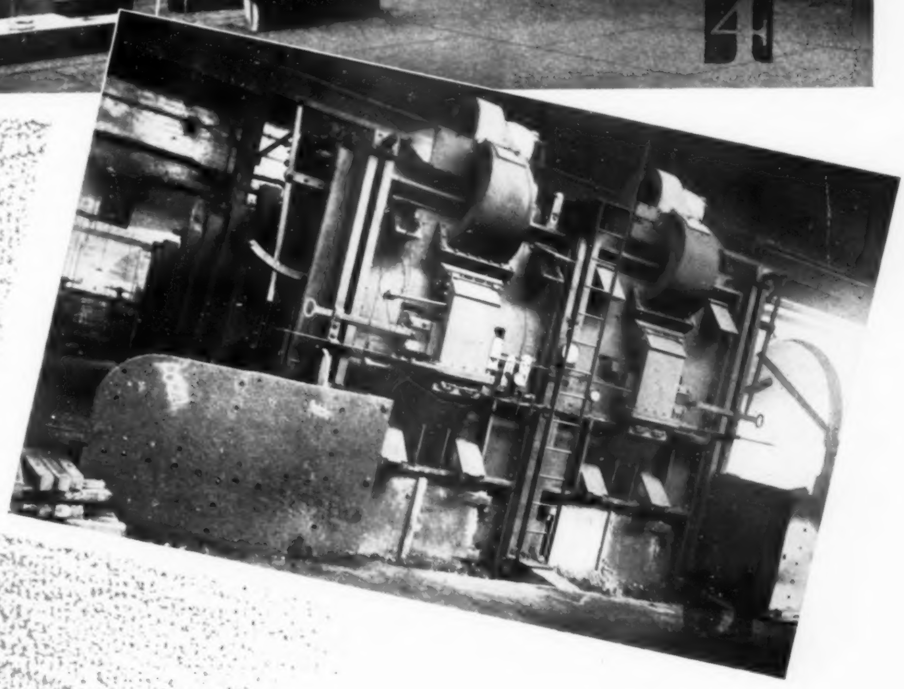

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

Characteristics a

CHROMIUM is primarily an alloying element, and exerts little or no scavenging effect on the metal with which it is alloyed. It is soluble in most metals, and alloys readily with iron, manganese, and tungsten. In some compositions containing chromium, formerly regarded as true alloys, accurate metallographic investigation has proved that they consist of mixtures with the chromium distributed in a finely divided condition. In the manufacture of steel, many of the beneficial results from additions of chromium are enhanced by the addition of other alloying elements, in addition to carbon, producing a combined effect greater than the effect of each element alloyed separately. Chromium is, however, a very important element, whether used alone or in combination with other alloying elements.

INFLUENCE OF CHROMIUM.

In commercial chromium carbon steels which are subjected to suitable heat-treatment, chromium imparts fineness of structure, giving increased strength with comparatively little loss of toughness and ductility; it also produces complex carbides of great hardness and strength. Chromium changes the position of the critical ranges and lowers the percentage of carbon required for the eutectoid ratio, and permits a lower critical rate of cooling. In the proper ratio with carbon, chromium has a very marked effect upon magnetic properties, and shows a very high resistance to atmospheric corrosion and to attacks by many chemicals; it imparts this property to its alloys, when a sufficiently high percentage of chromium is incorporated in the composition.

CHROMIUM-CARBON STEELS.

Chromium steels are conveniently classified according to their chromium content, and those containing up to 1% form a very comprehensive class, which includes the low-carbon casehardening steels, the medium-carbon steels required for strength, and the high-carbon steel for tool purposes; those with a higher percentage of chromium, between 1 and 2, form a class suitable for bearing steels; permanent magnet steels containing from 2 to 4% chromium, and stainless steels with from 12 to 14% chromium, are next in order.

LOW-CHROMIUM STEELS.

Low-chromium steels have a wide range of usefulness, both for structural and tool steel purposes. The increase in cost, due to the addition of chromium, is relatively small in comparison with the gain in strength, toughness, and wearing capacity, and the advantages of these steels are becoming increasingly recognised.

In casehardening steels containing carbon up to about 0.25%, the addition of 0.5% chromium has little effect on their physical properties other than that possible with a slightly increased carbon content in a straight carbon steel; but, for casehardening purposes, the chromium confers homogeneity, greater strength and wearing qualities, and, in casehardening operations which produce a high-carbon case, its use is of considerable importance. Chromium tends to emphasise the harmful effects of prolonged heating, and it is necessary to exercise care in the heat-treatment. Double quenching is advisable with these steels, and oil may be used for both quenchings, in view of the greater hardness and depth hardening resulting from the presence of the chromium. A casehardening steel of this type has the following chemical composition :—

Carbon.	Chromium.	Manganese.	Phosphorus.	Sulphur.
0.15—0.25 ...	0.60—0.90 ...	0.30—0.60 ...	0.40 max. ...	0.045 max.

The heat-treatment suitable for this steel is dependent upon requirements, but when hardness, refinement of the case, together with the minimum amount of distortion, are desired, it is recommended to carburise at 900—930° C. and quench in oil, reheat to 830—855° C. and quench, finally drawing at 120—250° C.

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and Uses of Chromium Steel

When this steel is used for casehardened gears, requiring a high degree of accuracy strength, normalising the gears at 870—925° C. before carburising will improve tructure and tend to reduce distortion by subsequent treatments.

Structural steels having a medium carbon content, with the addition of 0.5% nium, show an increase in tensile strength and elastic limit, after suitable heat-ment, over straight carbon steels with the same carbon manganese content of een 15 and 20%, while larger sections which are not heat-treated or annealed an increase in tensile strength between 5 and 10%. A typical chromium steel, ssing a wider heat-treating range with greater strength and toughness than a carbon steel, has the following composition :—

Carbon.	Chromium.	Manganese.	Phosphorus.	Sulphur.
0.35—0.45 ...	0.80—1.0 ...	0.50—0.80 ...	0.04 max. ...	0.04 max.

When this steel is used for forgings, the heat-treatment should follow normalising temperature of 885—940° C., subsequently reheating to 820—875° C., quenching , and drawing to the required hardness. This operation can be modified some- if the parts are to be machined after forging, but before final heat-treatment. n tool steels the influence of chromium becomes more marked with the increase rbon, increasing the hardness of the steel in greater proportion. Chromium with about 0.5% chromium and from 0.7 to 1% carbon have a special value ols such as chisels drills, saw-blades, files, razors, knives, and other sharp-edged In addition to giving increased surface hardness, chromium imparts greater hardening, and this is its advantage in tools, rather than any increased cutting rmance they may give.

BEARING STEELS.

hromium steels containing from 1 to 2% of chromium, together with high carbon out 1%, find considerable use in crushing machinery, safes, cones, roller bearings, ball races, tools, and other parts necessitating hard surfaces. Considerable s necessary in forging the steels within this range, which must be done at a good and the working as well as the temperature effects a change in the structure, ng it and breaking up the coarse structure, but leaving it very hard for machining tions. This condition is modified by annealing, the degree of softening required dependent upon the control of the temperature, both in heating and cooling, g the operation of annealing. Many factors must be considered in the annealing ss, in order to obtain a steel readily machinable, with a Brinell hardness of about out they are dependent upon the actual composition of the steel and the mass ved. After being machined, the various parts require to be heat-treated, and rocess develops in the steel a high degree of hardness.

STAINLESS STEELS AND IRONS.

hromium has the almost unique property of protecting itself against atmospheric sion. It has been suggested that a fresh surface of this element becomes oxidised t instantly, but the invisible film formed is of such a nature that it is impervious xtremely stable. The corrosive action which thus starts so rapidly is checked t immediately, corresponding to some extent with the elements aluminium and . This remarkable property of chromium is also imparted to its solid solutions n, when a comparatively high percentage of chromium is present. The marked nce to atmospheric attack seems to develop as the chromium is increased above n low-carbon alloys. Unless the carbon is exceptionally low, carbides are formed the chromium, which reduce the amount of this element in solid solution with on and reduce its resistance to corrosion attack. In the rustless irons containing ow percentages of carbon, 11 to 13% of chromium represents about the lowest ntration for the production of a very resistant surface.

In stainless steels suitable fo 14% ; but they generally contain heated, transforms wholly to aust in oil at about 1,010° C. develops remains in solution, and the stainl to nearly 480° C. Higher carbon dissolve sufficient of the chromium of dissolved chromium, if the stee

A familiar chromium-iron a very low carbon content. This allo for many purposes. The relativel being dissolved to maintain high

It was largely as a result o steels were discovered to have rema providing an ideal material for p composition of such a heat-resist

Carbon.	Chromium.	M
0.45—0.55 ...	8.0—9.0 ...	o

It will be noted that silicon i in order to reduce the air-hardeni to raise the critical range.

When exposed to heat, stain below 825° C. the scaling is almost slowly. The mechanical properti according to the carbon content. carbon content of 0.05 to 0.09% following approximate tests :—

Max. Stress, Tons per Sq. In.	Elongation, %
70—75 ...	11—13

With an increase of carbon to ment, show a tensile strength of c at 600° C. will give the following

Elastic Limit, Tons per Sq. In.	Max. Stress, Tons per Sq. In.	
58 ...	66	...

Stainless steels and irons are most important metallurgical deve to atmospheric corrosion and sca to the corrosive action of acids by other elements that may be p carbon on the resistance of iron- Manganese decreases the resistan acids, while carbon makes it more high acid resistance is desired, si manganese, with beneficial result

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In stainless steels suitable for cutlery, more chromium is usually present—namely, 14%; but they generally contain from 0.35 to 0.40% of carbon. This steel, on being heated, transforms wholly to austenite, and the carbide dissolves. Quenching this steel in oil at about 1,010° C. develops martensite of moderate hardness, but the chromium remains in solution, and the stainless property of the steel persists even after tempering to nearly 480° C. Higher carbon may be employed, but it is apparently necessary to dissolve sufficient of the chromium carbide to maintain a certain minimum concentration of dissolved chromium, if the steel is to retain its stainless properties after quenching.

A familiar chromium-iron alloy is that containing 16—18% chromium with a very low carbon content. This alloy supplies the need for a very soft but strong material for many purposes. The relatively high chromium content ensures an ample amount being dissolved to maintain high corrosion resistant qualities.

It was largely as a result of investigations on stainless steels that chromium steels were discovered to have remarkable resistance against scaling at high temperatures, providing an ideal material for parts subject to considerable heat. An approximate composition of such a heat-resisting steel for valves is as follows :—

Carbon.	Chromium.	Manganese.	Silicon.	Phosphorus.	Sulphur.
0.45—0.55 ...	8.0—9.0 ...	0.50 max. ...	1.5—3.0 ...	0.30 max. ...	0.03 max.

It will be noted that silicon is included in this composition; this has been added in order to reduce the air-hardening effect of the chromium-carbon combination and to raise the critical range.

When exposed to heat, stainless steel scales much less than ordinary steel, as below 825° C. the scaling is almost negligible, while at higher temperatures it proceeds slowly. The mechanical properties of this steel are remarkable, but vary somewhat according to the carbon content. The softer quality, known as stainless iron, with a carbon content of 0.05 to 0.09%, gives on hardening in oil, at 900° to 950° C., the following approximate tests :—

Max. Stress, Tons per Sq. In.	Elongation, %	Reduction in Area, %	Brinell.	Izod Impact, Ft.-lb.
70—75 ...	11—13 ...	35—40 ...	340 ...	35—40

With an increase of carbon to 0.35% a stainless steel will, given the same treatment, show a tensile strength of over 100 tons per square inch, and when tempered at 600° C. will give the following approximate mechanical tests :—

Elastic Limit, Tons per Sq. In.	Max. Stress, Tons per Sq. In.	Elongation, %	Reduction In Area, %	Brinell.	Izod Impact, Ft.-b.
58 ...	66 ...	17.5 ...	46 ...	321 ...	19

Stainless steels and irons are of great industrial value, and represent one of the most important metallurgical developments in recent years, as, in addition to resistance to atmospheric corrosion and scaling at high temperatures, they are also resistant to the corrosive action of acids; their corrosion resistance is, however, influenced by other elements that may be present in the alloys. The effect of manganese and carbon on the resistance of iron-chromium alloy to acid attack is very considerable. Manganese decreases the resistance of the alloy to both sulphuric and hydrochloric acids, while carbon makes it more susceptible to the attack of nitric acid also. When high acid resistance is desired, silicon may be used as a deoxidiser in preference to manganese, with beneficial results.

"Metallurgia" Chart, February, 1931.
The Kennedy Press, Ltd., Kennedy House,
Liverpool Road, Manchester.

Characteristics and Uses of

nent, and exerts little or no scavenging
oyed. It is soluble in most metals, and
and tungsten. In some compositions
true alloys, accurate metallographic
ixtures with the chromium distributed
cture of steel, many of the beneficial
ced by the addition of other alloying
ombined effect greater than the effect
is, however, a very important element,
r alloying elements.

HROMIUM.

hich are subjected to suitable heat-
ture, giving increased strength with
y; it also produces complex carbides
ges the position of the critical ranges
r the eutectoid ratio, and permits a
with carbon, chromium has a very
a very high resistance to atmospheric
imparts this property to its alloys,
is incorporated in the composition.

N STEELS.

ccording to their chromium content,
prehensive class, which includes the
rbon steels required for strength,
hose with a higher percentage of
ble for bearing steels; permanent
m, and stainless steels with from

STEELS.

usefulness, both for structural and
addition of chromium, is relatively
ghness, and wearing capacity, and
singly recognised.

p to about 0.25%, the addition
properties other than that possible
ight carbon steel; but, for case-
eity, greater strength and wearing
produce a high-carbon case, its
to emphasise the harmful effects
are in the heat-treatment. Double
e used for both quenchings, in view
from the presence of the chromium.
chemical composition :—

Phosphorus.	Sulphur.
0.40 max. ...	0.045 max.

pendent upon requirements, but
h the minimum amount of dis-
at 900—930° C. and quench in
ng at 120—250° C.

When this steel is used for casehardened gears, requiring a high de
and strength, normalising the gears at 870—925° C. before carburisi
the structure and tend to reduce distortion by subsequent treatment

Structural steels having a medium carbon content, with the ad
chromium, show an increase in tensile strength and elastic limit, afte
treatment, over straight carbon steels with the same carbon manga
between 15 and 20%, while larger sections which are not heat-treat
show an increase in tensile strength between 5 and 10%. A typical
possessing a wider heat-treating range with greater strength and to
plain carbon steel, has the following composition :—

Carbon.	Chromium.	Manganese.	Phosphorus.	
0.35—0.45 ...	0.80—1.0 ...	0.50—0.80 ...	0.04 max.	...

When this steel is used for forgings, the heat-treatment should fol
at a temperature of 885—940° C., subsequently reheating to 820—875
in oil, and drawing to the required hardness. This operation can be
what if the parts are to be machined after forging, but before final

In tool steels the influence of chromium becomes more marked w
of carbon, increasing the hardness of the steel in greater proporti
steels with about 0.5% chromium and from 0.7 to 1% carbon have
for tools such as chisels drills, saw-blades, files, razors, knives, and oth
tools. In addition to giving increased surface hardness, chromium i
depth hardening, and this is its advantage in tools, rather than any in
performance they may give.

BEARING STEELS.

Chromium steels containing from 1 to 2% of chromium, together w
of about 1%, find considerable use in crushing machinery, safes, cones,
balls, ball races, tools, and other parts necessitating hard surfaces
care is necessary in forging the steels within this range, which must be
heat, and the working as well as the temperature effects a change in
refining it and breaking up the coarse structure, but leaving it very har
operations. This condition is modified by annealing, the degree of sof
being dependent upon the control of the temperature, both in heatin
during the operation of annealing. Many factors must be considered in
process, in order to obtain a steel readily machinable, with a Brinell ha
165, but they are dependent upon the actual composition of the stee
involved. After being machined, the various parts require to be he
the process develops in the steel a high degree of hardness.

STAINLESS STEELS AND IRONS.

Chromium has the almost unique property of protecting itself agai
corrosion. It has been suggested that a fresh surface of this element be
almost instantly, but the invisible film formed is of such a nature that i
and extremely stable. The corrosive action which thus starts so rap
almost immediately, corresponding to some extent with the elements
silicon. This remarkable property of chromium is also imparted to its
in iron, when a comparatively high percentage of chromium is present
resistance to atmospheric attack seems to develop as the chromium is i
10% in low-carbon alloys. Unless the carbon is exceptionally low, carb
with the chromium, which reduce the amount of this element in solid
the iron and reduce its resistance to corrosion attack. In the rustless i
very low percentages of carbon, 11 to 13% of chromium represents ab
concentration for the production of a very resistant surface.

f Chromium Steels.

high degree of accuracy
arburising will improve
eatments.
the addition of 0.5%
nit, after suitable heat-
manganese content of
at-treated or annealed
ypical chromium steel,
and toughness than a

s.	Sulphur.
...	0.04 max.

ould follow normalising
20—875° C., quenching
can be modified some-
re final heat-treatment.
rked with the increase
proportion. Chromium
n have a special value
and other sharp-edged
omium imparts greater
n any increased cutting

gether with high carbon
, cones, roller bearings,
surfaces. Considerable
must be done at a good
nange in the structure,
ery hard for machining
e of softening required
n heating and cooling,
dered in the annealing
rinell hardness of about
the steel and the mass
o be heat-treated, and

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elf against atmospheric
ment becomes oxidised
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so rapidly is checked
ements aluminium and
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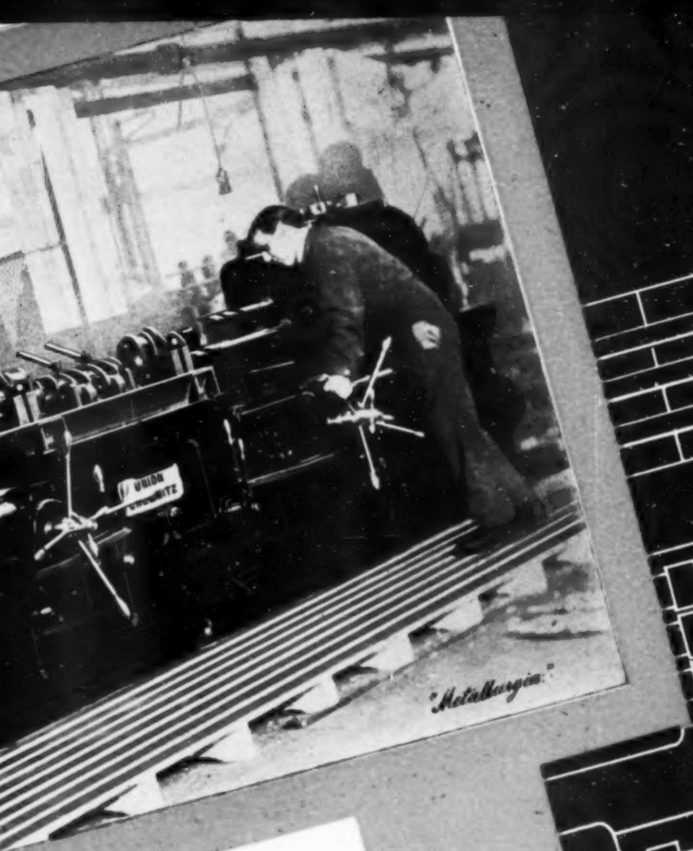

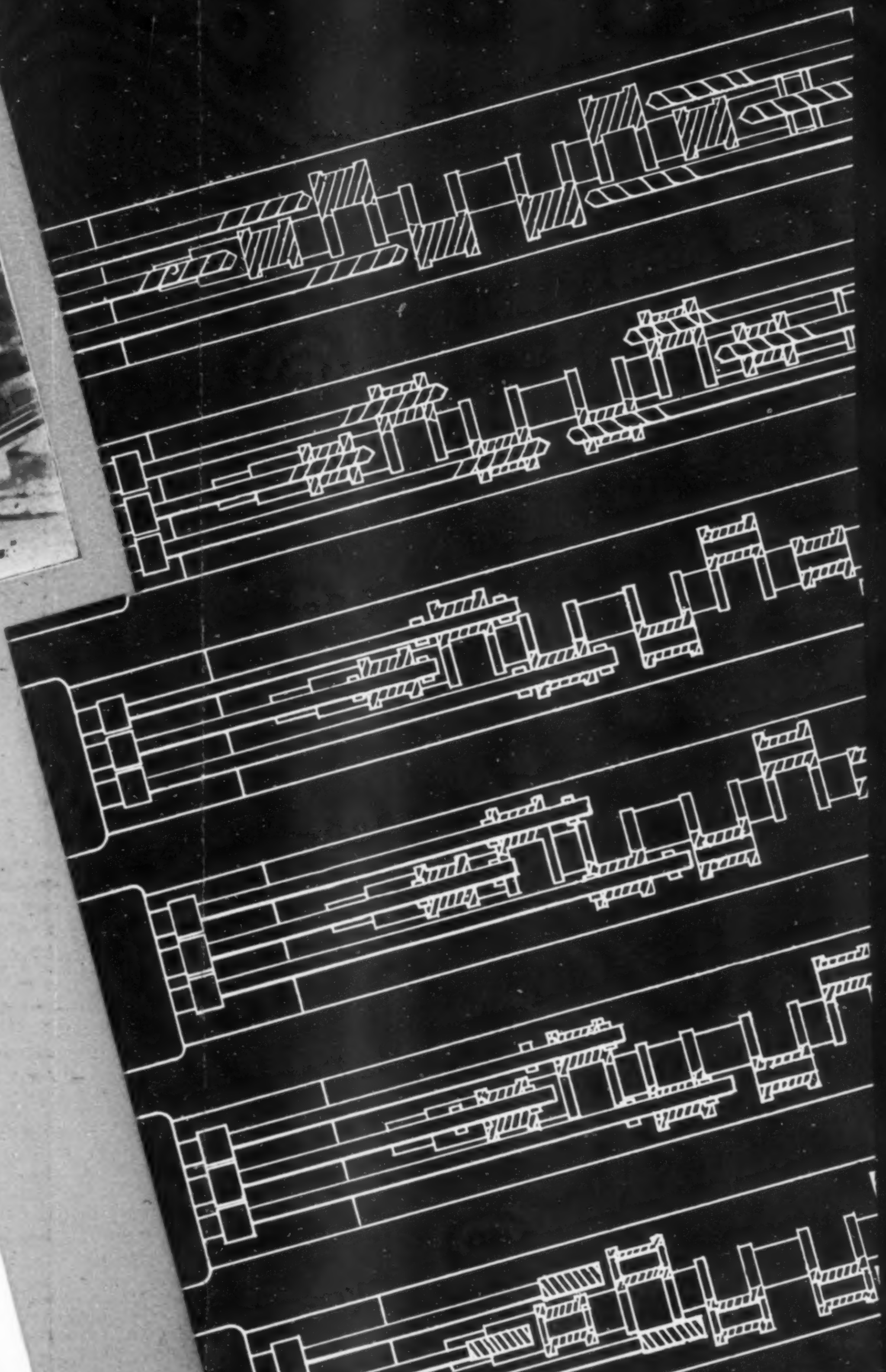

...i Automatic ...lling Machine ...land Crank-Shafts

...he famous "UNION" Horizontal
...lly for drilling, recessing, and
...rank-shafts. The installation as
...d Motors, Ltd., upon four- and
...ous line of Leyland 'buses.

...for drilling either four-throw or
...rations are performed automatically
...ds. After drilling, the drills are
...ial and positive bayonet joints which
...ks. Then boring bars are placed in
...averse through the holes as drilled,
...the recessing of both ends of the holes.
...anged for reamers in the same handy
..." sized."

...e operation, and the starting of coolant
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...es ; spindle revolutions, feed and coolant
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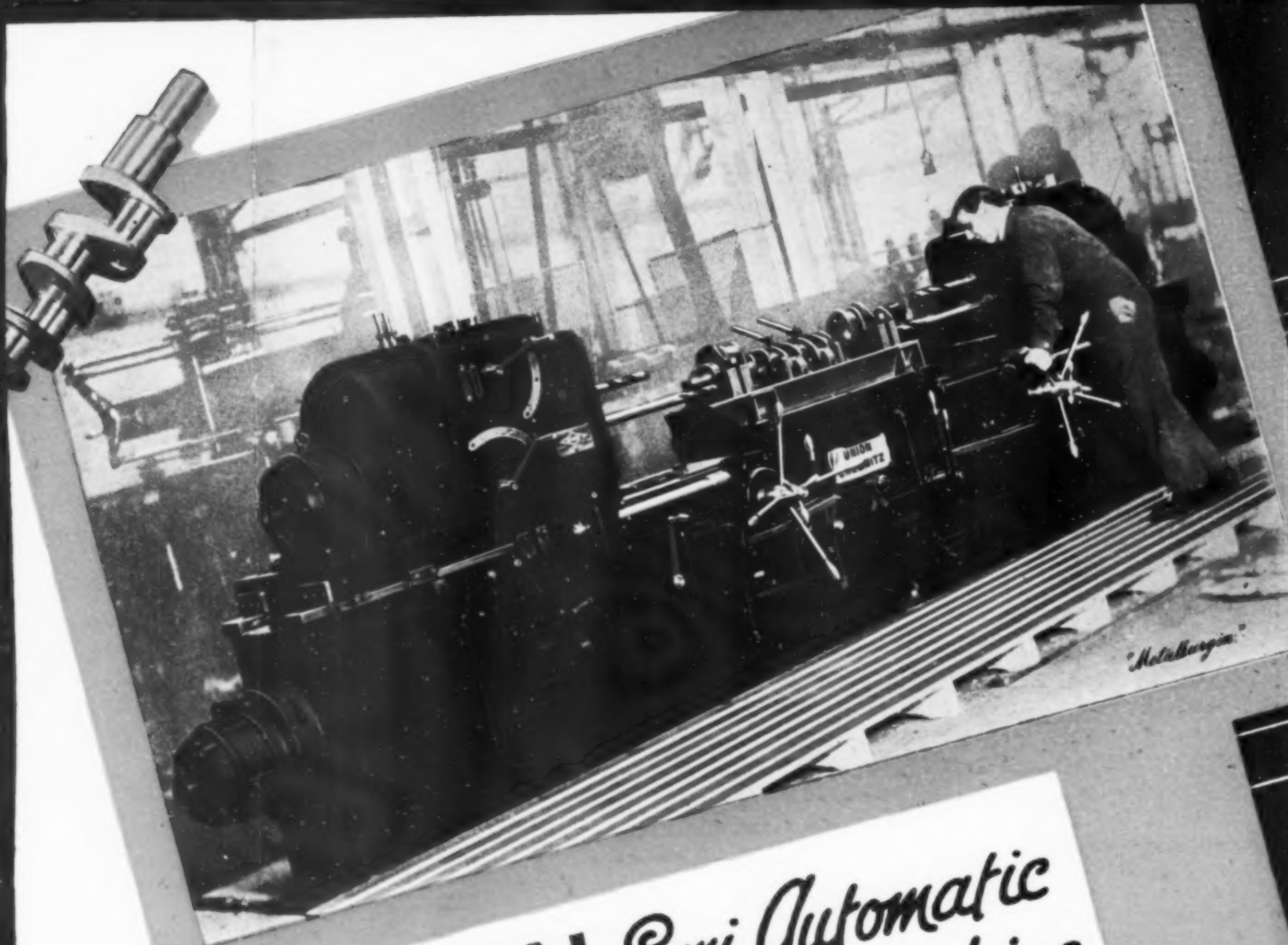
...

...aneous and automatic to fixed stops ; one
...he movement for back recesses.



The UNION Semi Automatic Crank Shaft Drilling Machine

Drilling Leyland Crank-Shafts

This machine, built by the makers of the famous "UNION" Horizontal Boring Machine, is designed specially for drilling, recessing, and reaming the pins of automobile crank-shafts. The installation as shown is working at Messrs. Leyland Motors, Ltd., upon four- and six-throw crank-shafts for the famous line of Leyland 'buses.

The machine is equally suitable for drilling either four-throw or six-throw cranks. The drilling operations are performed automatically and simultaneously by both heads. After drilling, the drills are removed by one half turn in special and positive bayonet joints which disengage the Morse taper shanks. Then boring bars are placed in position, advanced in quick traverse through the holes as drilled, and recessing tools inserted for the recessing of both ends of the holes. Then the recessing tools are changed for reamers in the same handy fashion and the holes finally "sized."

The feed of the tools, spindle operation, and the starting of coolant flow, all occur simultaneously, and their action is automatic to the point of completing the holes; spindle revolutions, feed and coolant supply then simultaneously stop, feed reversing rapidly to starting position—all automatically.

Front recessing is simultaneous and automatic to fixed stops; one lever movement repeats the movement for back recesses.

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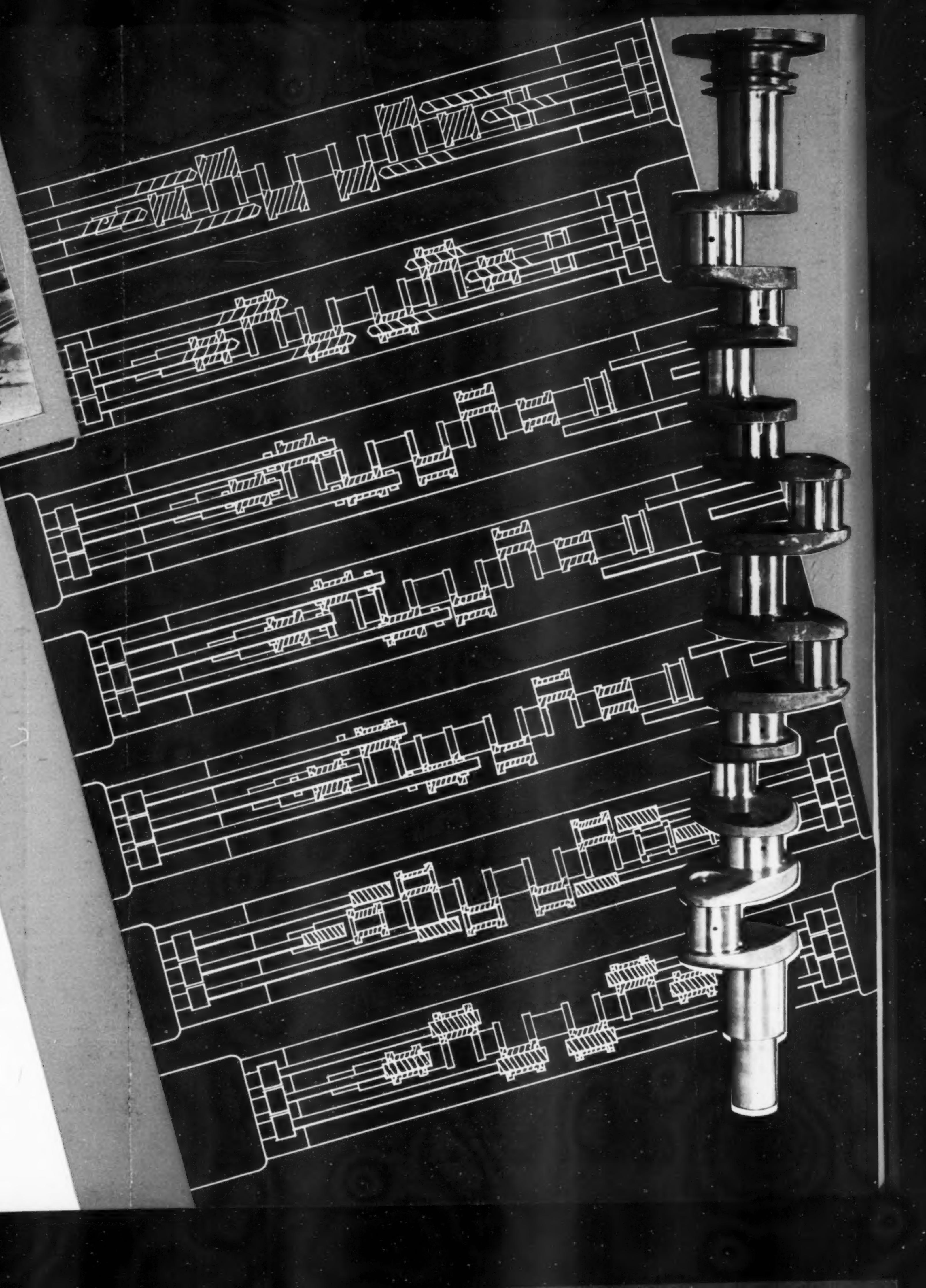

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

Characteristics and

CONSTITUTIONAL EFFECTS OF NICKEL AND CHROMIUM.

THE constitutional effects of nickel and chromium on steel differ from each other in that, whilst the nickel, by alloying with the ferritic constituent, produces increased strength and toughness, the chromium forms a double carbide which has a hardening and strengthening effect on the steel. The general effect is to provide a steel which possesses both high tensile strength and a very good ratio of yield point to maximum stress, coupled with exceedingly good toughness and ductility. At the same time the chromium raises the Ac change point whilst the action of the nickel is to lower this, the combined effect resulting in either a slight increase or decrease according to the actual chemical composition.

The presence of nickel and chromium enables a reduced hardening rate to be used through the critical range, their combined effect being, in fact, rather greater than that of either of the metals alone. This results in the full hardening effect being obtained by a less drastic quenching, and also the depth of penetration of hardness is much greater. When sufficient amounts of these two elements are present, cooling in air is all that is required to obtain the necessary hardness. The general effect is to provide steels in which it is possible to ensure uniform hardening in quite large sections, and also to lessen distortion because of the slower quenching rate which is possible.

RANGE OF NICKEL CHROMIUM STEELS.

It is not proposed in this chart to give any details of the high-nickel-chromium austenitic steels which have been developed for heat and corrosion resisting purposes, but to confine the data to those steels which contain from 1 to 5% and 0.5 to 1.5% of nickel and chromium, respectively.

These steels can be conveniently divided into two classes :—

(*a*) Casehardening steels.
(*b*) Structural steels.

CASEHARDENING STEELS.

Whilst for many years the plain carbon and also the nickel casehardening steels have given excellent service in their respective spheres, there has in recent years been a considerable development in the use of nickel-chromium casehardening steels. This has been brought about to a large extent by the continual increase in tooth loading in the case of gears, so that it has been necessary to find a steel which would have a core possessing sufficient strength to withstand the high crushing loads now in use.

By a suitable combination of nickel and chromium together with an appropriate heat-treatment, it is possible to obtain casehardening steels which will have a core strength of from 60 to 100 tons per sq. in.

The following compositions are typical of the nickel-chromium casehardening steels :—

TABLE I.

CASEHARDENING STEELS : PERCENTAGE CHEMICAL COMPOSITION.

Steel.	C.	Si (Max.)	Mn.	S (Max.)	P (Max.)	Ni	Cr.
A	0·12 to 0·16	0·30	0·30 to 0·50	0·04	0·04	3·25 to 3·75	0·6 to 0·8
B	0·08 to 0·13	0·30	0·25 to 0·45	0·04	0·04	3·25 to 3·75	0·8 to 1·1
C	0·14 to 0·18	0·30	0·35 to 0·45	0·04	0·04	4·0 to 4·5	1·0 to 1·3

l Properties of Nickel-Chromiu

These steels, after suitable heat-treatment, may be relied upon to give figures uch as are shown in the following table, which shows the average values to be xpected from these particular steels :—

TABLE II.

CASEHARDENING STEELS : TYPICAL PHYSICAL TESTS OF CORE.

eel.	Final Heat Treatment.	Yield Point, Tons/Sq. In.	Max. Stress, Tons/Sq. In.	Elongation, %.	Reduction of Area, %.	Izod Impact, Ft.-Lb.
A	Water quench, 780° C.	50	67	18	40	43
A	Oil quench, 780° C. ..	41	57	20	44	50
B	Water quench, 770° C.	57	76	16	39	40
B	Oil quench, 770° C. ..	44	63	19	43	47
C	Oil quench, 770° C. .. Temper. 175° C.	80	91	15	45	31

The carburisation of nickel-chromium steels is carried out in the usual way, and it ill be found that the rate of penetration of carbon, whilst naturally depending on e temperature, will be slightly lower than that for a plain carbon steel carburised nder identical conditions. Before the carburising operation is carried out it is dvisable to normalise the steel components, as this has a beneficial effect in minimising ny subsequent distortion which might take place. The normal temperature for rburisation is 900° C., but under special circumstances this may be raised or lowered suit particular requirements. After carburisation the heat-treatment usually onsists of a double oil quench, the first from a temperature of from 840—860° C., nd the second from a temperature of from 760—780° C. The latter quench may also e carried out in water in special circumstances, but in general an oil quench is recom- ended, as although it may be at the sacrifice of a very slight amount of hardness in the se, there is a gain in the increased toughness, and absence of, or decreased, distortion hich results.

In cases where the shape of a component is somewhat intricate, it is advantageous substitute a single oil quench from about 780° C. in order to minimise as far as ossible the distortion.

Owing to the intensive hardening which takes place with these steels, a beneficial fect can be obtained by a final tempering operation, in which the articles are heated oil at a temperature of from 150—200° C., for one hour or more. This operation sults in an appreciable increase in the elastic limit, yield point, and toughness, without ppreciably affecting the hardness.

STRUCTURAL STEELS.

In order to obtain the optimum properties from nickel-chromium steels it is cessary to use them in the hardened and tempered condition. By varying the mpering temperature it is possible to obtain a very big range of properties from any e steel, but it should be kept in view that high tensile strength which is obtained by a w-tempering temperature, is accompanied by comparatively low ductility. On the her hand a high-tempering temperature results in a lower tensile strength, but this accompanied by high toughness and ductility.

Whilst it is possible to obtain a very large range of tensile strength from any one eel, it will be found convenient to classify the structural nickel-chromium steels follows :—

(*a*) Those steels possessing a tensile range of 55—65 tons per sq. in.

(*b*) Those steels possessing a tensile range of 65—75 tons per sq. in.

(*c*) Those steels possessing a tensile range of 100 tons per sq. in. and over.

The following table gives the chemical composition of steels which can be used the above ranges.

STRUCTU

—	C
A	0·25 to 0
B	0·22 to 0
C	0·35 to 0
D	0·25 to 0

The followin the above steels

S

Steel.	Hardeni
A	Oil quen 830° C
B	Oil quen 830° C
C	Oil quen 830° C
D	Air quen 820° C

Whilst the s should be confin are used in the to that for steel purpose. Menti known as " ten but it can be st sition, one being Actually no tro by the simple e addition of sma

In general this is accomp

Nickel-chr mobile and airc variety of gear it is interesting railways for lo

Further ap industry nickel uses include dr and rolls for sp ingly employed locomotive fra

ıaracteristics and Properties of Ni

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AGE CHEMICAL COMPOSITION.

S (Max.)	P (Max.)	Ni	Cr.
·04	0·04	3·25 to 3·75	0·6 to 0·8
·04	0·04	3·25 to 3·75	0·8 to 1·1
·04	0·04	4·0 to 4·5	1·0 to 1·3

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ESTS OF CORE.

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	45	31

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—	C	Si (Max.)	Mn.	S (Max.)	P (Max.)	Ni	Cr.
A	0·25 to 0·35	0·30	0·45 to 0·70	0·05	0·05	3·0 to 3·75	0·50 to 1·0
B	0·22 to 0·28	0·30	0·35 to 0·65	0·05	0·05	2·75 to 3·5	1·0 to 1·4
C	0·35 to 0·42	0·30	0·45 to 0·65	0·05	0·05	1·25 to 1·75	0·75 to 1·25
D	0·25 to 0·32	0·30	0·35 to 0·60	0·05	0·05	3·75 to 4·50	1·0 to 1·5

The following table gives typical physical properties which can be expected from the above steels when suitably heat-treated :—

TABLE IV.
STRUCTURAL STEELS: TYPICAL PHYSICAL TESTS.

Steel.	Hardening.	Tempering.	Yield Point, Tons/Sq. In.	Max. Stress, Tons/Sq. In.	Elongation %.	Reduction of Area, %.	Izod Impact, Ft.-Lb.
A	Oil quench, 830° C.	Oil quench, 625° C.	55	60	22	62·5	68
B	Oil quench, 830° C.	Oil quench, 540° C.	65	71	19·5	58·5	52
C	Oil quench, 830° C.	Oil quench, 200° C.	94	109	12	36	15
D	Air quench, 820° C.	Oil quench, 200° C.	96	111	12	38	18

Whilst the steels have been classified as above, it must not be considered that they should be confined to the particular ranges given ; for instance whilst steels C and D are used in the " 100 ton " condition for gears, steel A, after a heat-treatment similar to that for steel C, will give equally good properties, and is, in fact, used for a similar purpose. Mention may be made of the fact that some steels are subject to what is known as " temper-brittleness," the actual cause of which is not definitely known ; but it can be stated that it is possible to have two steels of identical chemical composition, one being susceptible to and the other being entirely free from this phenomenon. Actually no trouble is experienced in practice, as " temper-brittleness " is prevented by the simple expedient of quenching in either oil or water after tempering. Also, the addition of small amounts of molybdenum acts as a preventative.

In general, it is advisable to avoid tempering in the range 275° C. to 450° C., as this is accompanied by comparatively low Izod impact values.

GENERAL APPLICATIONS.

Nickel-chromium steels have found their most important application in the automobile and aircraft industries—for crankshafts, connecting rods, axle shafts, a wide variety of gears and other stressed components. In the heavier fields of engineering it is interesting to note that nickel-chromium steels are being extensively used on the railways for locomotive connecting rods, piston rods, and coupling rods.

Further applications are for cranks for forging presses, while in the drop-stamping industry nickel-chromium steel die blocks are used in considerable quantities. Other uses include dredger bucket pins, eyebars and pins for bridges, bolts for steam plant, and rolls for special purposes, while nickel-chromium steel castings are being increasingly employed for use in making caterpillar tracks, rack and pinion movements, locomotive frames, trackwork, crusher jaws, and many other similar applications.

" Metallurgia " Chart, March, 1931.
The Kennedy Press, Ltd., Kennedy House,
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by a New Metal

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

Molybdenum, I

ALTHOUGH isolated by P. J. Hjelm, a Danish chemist, as far back as 1782, it is only during comparatively recent years that the value of molybdenum has been appreciated. It was tried for many years as a competitor with tungsten for high-speed tool steels, but molybdenum steels gave trouble owing to seaminess and their liability to crack, with the result that tungsten was mainly used for this purpose. During the War, however, there was a shortage of tungsten and molybdenum was largely employed. It was only as a result of much research that the main difficulties then associated with the production of molybdenum steel were overcome. While it is not likely to displace tungsten in the manufacture of high-speed tool steels, investigations have shown that it has a remarkable influence as an alloying element in steel. Its addition to a straight carbon steel, for instance, greatly improves the physical qualities of the steel, but it is chiefly in combination with other alloying elements, such as nickel, chromium, vanadium, etc., that the demand for molybdenum is growing at a considerable rate. It has the effect of intensifying the beneficial properties of these elements in addition to exercising its own special functions.

The functions of molybdenum in a steel are essentially to exert a powerful influence in improving the physical qualities, in promoting fine grain structure, in eliminating temper brittleness, in reducing the effect of mass, and in giving permanency to the physical properties which enable the steel to resist abnormal conditions during service and when subjected to wide temperature variations.

MOLYBDENUM MINERALS.

Molybdenum is associated with acid rocks, such as granite, and thus presents a contrast to chromium, which occurs in basic rocks. Molybdenum minerals are also frequently found in quartz lodes and pegmatite dykes that spring from acid intrusive masses. The most important mineral is the sulphide—molybdenite, MoS_2—which occurs in crystals or fine flakes and granules, having a greyish metallic lustre similar to that of graphite. In the oxidised portions of the veins or rocks, the weathering of the molybdenite and pyrites has produced a hydrated molybdate of which the composition is variable, but of which iron appears to be an essential constituent. Another mineral containing molybdenum, lead molybdate, is also found in natural form. This is a yellow mineral known as Wulfenite, $PbMoO_4$, which is often more or less transparent, with an adamantine lustre.

At one time Australian deposits supplied about 70% of the world's needs, but, during recent years, the majority has been supplied by the United States of America, where the most important molybdenite ores occur. In addition to these countries are Canada and Norway, where ores are found, while China at one time supplied a considerable quantity. The steadily increasing consumption of molybdenum is stimulating search for, and the attempted development of, many prospective sources. Occurrences of the metal are widely distributed throughout the world, but seldom are deposits found which, from a tonnage point of view, are worthy of commercial consideration.

In most cases deposits of molybdenite occur in small flakes and granules embedded in quartz-reef or distributed through granite or pegmatite, and in nearly every case some form of concentrating plant must be installed. It is customary to erect concentrating plant near the mine, of course, in order to eliminate part, at least, of the valueless matter and produce a material rich enough to be sent to the smelter. The process of concentration depends upon the character of the gangue minerals, but the usual system is that of flotation. For many ores the Elmore vacuum process appears to be particularly suited.

Its Ores, Methods of Extraction

ELMORE VACUUM FLOTATION PROCESS.

In this process the ore is finely ground in a ball mill with a small quantity of pine oil and kerosene, and the pulp produced passes on to a mixer, from which it flows continually, and is sucked through a pipe into a container in which a vacuum is maintained by means of an exhaust pump. The reduced pressure in the container causes the air dissolved in the water to be liberated, which forms a froth in the upper part. Each bubble of air in the froth is surrounded by a thin film of oil, and as the particles of molybdenite cling to the oil films, surrounding the bubbles, they remain suspended in the froth, while the gangue particles sink to the bottom of the container. A rotating shaft, in the centre of the container, to which are attached rakes, gradually works the worthless particles at the bottom to the edge, and they pass out through a pipe, while the froth, bearing the molybdenite particles, overflows continually and is carried through another pipe as the concentrate.

In some instances the ores contain other sulphides, such as pyrites, and there is a tendency for these other sulphides to adhere to the froth as well as the molybdenite. It has, however, been found possible to separate molybdenite from pyrites by selective flotation under suitable conditions.

FERRO-MOLYBDENUM.

A considerable proportion of the molybdenum concentrates is used for the preparation of ferro-molybdenum, an alloy of iron and molybdenum, containing from 60/80% molybdenum. In this form it was mainly used for the addition of molybdenum to steel, but in present steelmaking practice the ferro-alloy has been largely replaced by calcium molybdate or by certain combinations of lower oxides of molybdenum with lime and silica, one of which is marketed under the trade name of "Molyte."

Ferro-molybdenum is made in the electric furnace either by smelting raw or roasted concentrates in admixture with suitable fluxes, and with the addition of iron, the amount of this depending on the grade of alloy required. There is also a considerable production of ferro-molybdenum by thermit methods; this process being particularly valuable where the carbon free alloy is required.

CALCIUM MOLYBDATE, ETC.

Calcium molybdate and similar products may be made by wet or dry methods, or by a combination of both. Calcium molybdate is generally sold as a powder and packed in linen bags. The contents of the bags are adjusted so that each package contains a definite weight of molybdenum—5 or 10 lb.,—this being convenient for the addition of definite quantities of molybdenum to the steel bath. Products of the "Molyte" type are sold in pieces varying from walnut to fist size; the molybdenum contents range from 40 to 45%. Calcium molybdate is particularly suitable for basic steel, while "Molyte" is more suitable for metal made on an acid lining.

METALLIC MOLYBDENUM.

Metallic molybdenum may be prepared by reduction of molybdenum trioxide with carbon in the electric furnace, or by alumino-thermic methods. The metal so obtained has been fused in the course of manufacture, and may contain over 99% molybdenum. There is little or no demand for this product, and molybdenum metal, as occurring in commerce, is either a powder obtained by carbon or hydrogen reduction of the trioxide, or as sheet or wire; the latter forms being prepared from the hydrogen reduced powder.

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Molybdenum powder, prepared by heating the oxide with carbon, generally contains between 96 and 98% molybdenum. It has a limited application in the preparation of special alloys, but the demand is very small in comparison with ferro-molybdenum, etc. The hydrogen reduced powder contains 99.90/100.00% molybdenum, and is used for the preparation of molybdenum sheet and wire. The malleable and ductile metal is prepared by pressing the powder into small bars, which are strengthened by a heating process known as sintering, and finally raised to a high temperature by electrically heating. The sintering and final heating are performed in a non-oxidising atmosphere. Sheet or wire is produced from the bars by the usual processes of swaging, rolling, and drawing.

CHARACTERISTICS AND PROPERTIES.

Molybdenum is a silvery white metal which has general properties somewhat resembling the metal chromium. Although superficially oxidised at high temperatures, it is not perceptibly altered by exposure to the atmosphere at ordinary temperatures, except in a finely divided condition. It is probable that this metal is protected by an oxide film, in a similar manner to a number of other metals, and this may have some influence in protecting it against acids, since it is not readily dissolved by acids, although nitric acid, concentrated sulphuric acid, and hydrochloric acid attack it perceptibly. Although the oxide of molybdenum is not freely soluble in acid, it is soluble in alkali, forming a molybdate. The oxides of iron and nickel on the other hand, are soluble in acid but not in alkali.

Molybdenum is not naturally ductile, but if required in the form of wire, it can be rendered ductile and fibrous by swaging. Melting point, 2550° C.; boiling point, 3617° C.; atomic weight, 96.0; specific gravity, 10.2; specific heat at 0° C.: 0.0720; linear coefficient of expansion at 40° C. $\times 10^4$: 0.0515; specific resistance, microhms per cub. cm.: 4.8 — 5.6; electrical conductivity at 0° C. (Cu 100), 32.9 — 28.2; thermal conductivity at 0° C.: 0.3460; tensile strength, tons per sq. in., 110.

APPLICATIONS OF MOLYBDENUM.

Although it owes its importance primarily to its value as an alloying element in steel, it has been established that molybdenum definitely improves grey cast iron and malleable cast iron also. For many purposes it is probable that the merits of this alloying element can only be ascertained by extensive and carefully checked trials, but perhaps the best indication of its success is its increasing application in the manufacture of high-quality steels, grey cast iron, and malleable cast iron. As its usefulness in this respect becomes more appreciated, new applications as an alloying medium will undoubtedly arise. Pure molybdenum, as sheet and wire, has extensive applications in electrical work where it is employed in the construction of thermionic valves, X-Ray tubes, and as a support for the filament in incandescent electric lamps. There is a use for molybdenum wire in laboratory resistance furnaces, where a temperature approaching 1750° C. is required. The furnace is wound with molybdenum wire which is electrically heated. Oxidation of the wire is prevented by maintaining an atmosphere of hydrogen in contact with it. Molybdenum is also a constituent of "Stellite," an alloy of cobalt, chromium, Tungsten, and molybdenum, characterised by retention of hardness at high temperature and resistance to corrosion.

"Metallurgia" Chart, April, 1931.
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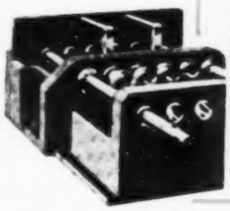

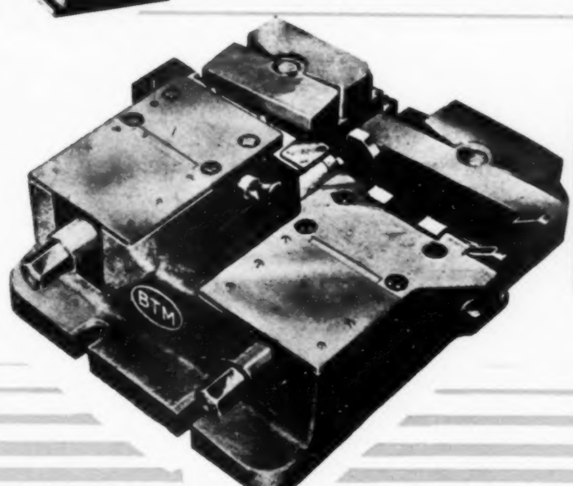

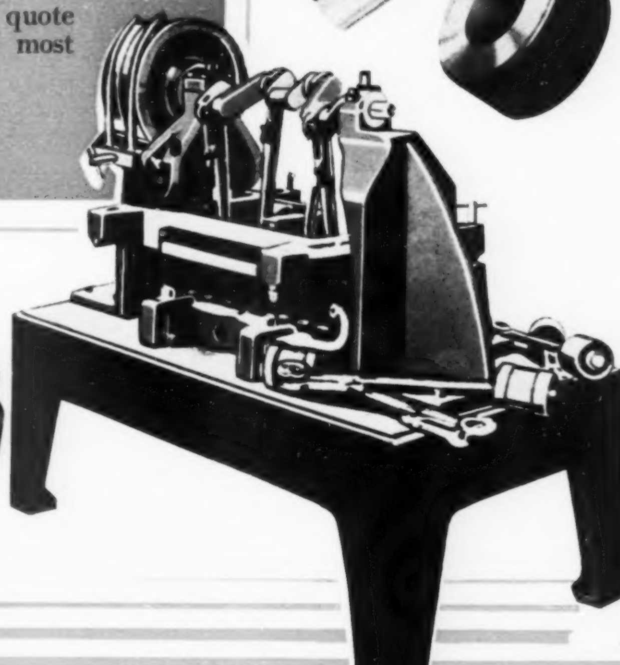

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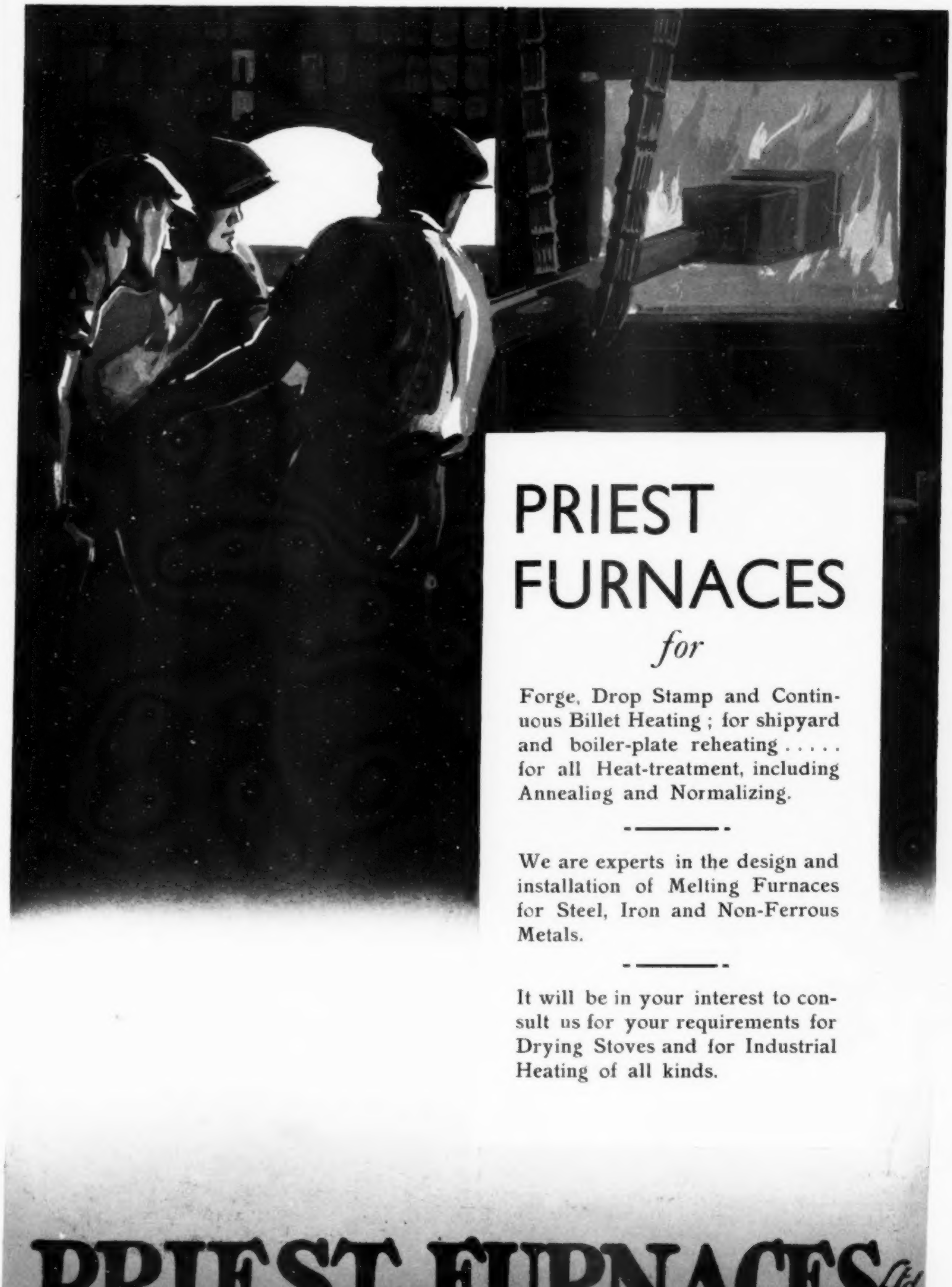
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